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OUTLINES OF ZOOLOGY.

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ZOOLOGY

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PREFACE.

THIS book is intended to serve as a manual which Students of Zoology may use in the lecture room, museum, and laboratory, and as an accompaniment to several well-known works, cited in the Introduction, most of which follow other modes of treatment. The volume is, in great part, a re-edition of manuscript notes which I have sometimes circulated among my students in order to facilitate both their work and mine. Considering the limited size and purpose of the book, I have seldom thought it necessary to cite the authorities from whose works the facts have been obtained.

To these authorities, especially to those cited in the "Notes on Books," I acknowledge my indebtedness. I desire also to record my obligations to three friends, to Mr. G. S. Corstorphine, B.Sc., for his revision of the proof-sheets and for the index, to Mr. Norman Wyld, for most of the chapter on physiology, and to Mr. William Smith, for the care he has taken in drawing the illustrations.

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OUTLINES OF ZOOLOGY.

CHAPTER I.

GENERAL SURVEY OF THE ANIMAL KINGDOM.

THE simplest animals (PROTOZOA) are mostly unit masses of living matter or single cells, and are thus contrasted with all the other animals which are many-celled (METAZOA). But these rigid divisions are never quite true, for some Protozoa form balls of cells and thus bridge the gulf.

It is customary to divide the Metazoa into two sets, backboneless animals (INVERTEBRATA) and backboned animals (VERTEBRATA), and the distinction is practically useful. Nowadays, the favourite terms are NON-CHORDATA and CHORDATA. We may contrast the two sets as follows:—

BACKBONELESS, INVERTEBRATE, NON-CHORDATE.	BACKBONED, VERTEBRATE, CHORDATE.
Ventral, or lateral, never dorsal nerve-cords.	Dorsal nerve-cord (spinal cord, brain).
	Dorsal supporting rod (notochord, replaced in most by a backbone).
	Gill-slits (or visceral clefts) from the pharynx to the exterior (not used for respiration above amphibians).
The eye is usually derived directly from the skin.	The essential parts of the eye are formed from an outgrowth of the brain.
The heart is dorsal.	The heart is ventral.

But all these hard and fast distinctions are apt to be misleading. No zoologist can draw the boundary line between Invertebrates and Vertebrates with a steady hand. We hardly know where the backboned series begins,—whether with the worm-like *Balanoglossus* and *Cephalodiscus*, or with the degenerate Tunicata, or with the remarkable lancelet (*Amphioxus*). Moreover, not a few Invertebrate animals (Nemertean "worms," Chætopod "worms," and even Crustaceans) approach Vertebrates in some of their features.

Before we begin with the Invertebrate animals, we must answer the question, "How do you know where to start?" In other words, we have to explain the "basis of classification." We begin with the animals of simpler structure, as we would begin architectural studies with the simplest buildings. We pass thence to more complex forms, and, of course, we together rank those which show a similar style of architecture. To some extent we are helped in our order of procedure by the study of extinct animals and their gradual appearance upon the earth (Palæontology). But the oldest rocks with certain and intelligible fossils, contain many types of different degrees of complexity, and we cannot tell from this study alone in what precise order the simpler animals were evolved. We get more help from the study of individual development (Embryology). Thus we learn that most young embryos have the form of a two-layered sac of cells, a *gastrula*. This gastrula occurs with great constancy in the development of animals, and the conclusion suggested is that the earliest and simplest Metazoa were like gastrulæ.

Classification is based upon structural resemblances (homologies); it follows the path of gradually increasing complexity (differentiation); it is corroborated by the results of embryology and palæontology.

General Classification.

Protozoa—unicellular.
Rhizopods, Infusorians, and Gregarinids.

Metazoa—multicellular.

Non-Chordate, Invertebrate, or Backboneless.	Chordate, Vertebrate, or Backboned.

INVERTEBRATE METAZOA.

After the unicellular Protozoa, we begin with those multicellular animals which are least removed from the gastrula-type, with the Sponges (PORIFERA). Next we rank the Stinging-animals (zoophytes, jellyfish, sea-anemones) or CŒLENTERATA, because their simplest forms are not much more than gastrulæ.

The first two classes of Metazoa—the Sponges and the Stinging-animals—are contrasted in some important features with all the higher forms.

SPONGES AND CŒLENTERATA.	HIGHER ANIMALS (CŒLOMATA).
There is no body-cavity. There is but one cavity, that of the food-canal.	There is a body-cavity or cœlome between the food-canal and the walls of the body. But this body-cavity is often only incipient, or else almost obliterated.
There is no definite middle layer of cells (mesoderm), but rather a middle jelly (mesoglœa).	There is a distinct middle layer of cells (mesoderm) between the external ectoderm and the gut-lining endoderm.
The symmetry of the gastrula is retained in the adult, that is, the longitudinal (oral-aboral) axis of the adult corresponds to the long axis of the gastrula.	The longitudinal (head to tail, oral-aboral) axis of the animal does not correspond to the long axis of the gastrula.

Next to the Stinging-animals, I think that the simplest "worms" should be ranked. To rank Echinoderms next Cœlenterates, as many text-books do, is confusing. Though they seem to agree in symmetry, the transition is very abrupt. The simplest "worms" (Turbellarians), however, are not very far above the gastrula level.

But beyond this beginning, we have little clear light. There is no class of "worms," but an assemblage of classes whose affinities are hard to determine. The word "worm"

is a name for a mere *shape* which animals of very diverse structure have assumed. They have begun to move head foremost, and to acquire sides. In this "mob" we may, however, recognise that the simpler worm-like forms are unjointed or unringed. They are thus contrasted with ringed or segmented "worms," such as the earthworm. But this segmentation appears gradually. In our discussion we shall observe the following order :—

Flat Worms or Plathelminthes.	Turbellaria. Planarians (free-living). Trematoda. Flukes (parasitic). Cestoda. Tapeworms (parasitic).
	Nemertea. Ribbon-worms (free-living). Nematoda. Thread-worms (many parasites). Some small classes.
Annelids or Ringed Worms.	Chætopoda. Bristle-footed worms, *e.g.*, earthworm and lobworm. Discophora or Hirudinea. Leeches (external parasites). Some small sets.
?	Sipunculoidea, *e.g.*, *Sipunculus*. Bryozoa or Polyzoa, *e.g.*, *Flustra*, the sea-mat. Brachiopoda. Lamp-shells.

In the mean time, however, be assured that there is no class of worms, but think of the assemblage of classes as in the centre of the invertebrate animals, with affinities on all sides,—to Echinoderms, Arthropods, Molluscs, and Vertebrates. They lie in a pool from which many streams flow.

It is probable that the well-defined series of ECHINODERMATA—star-fishes, sea-urchins, etc.,—had their origin in some worm-like type. There are seven classes, of which two are wholly extinct.

Holothuroidea. Sea-cucumbers.

Echinoidea. Sea-urchins.

Asteroidea. Star-fishes.
Ophiuroidea. Brittle-stars.

Crinoidea. Feather-stars.
Cystoidea. } Extinct.
Blastoidea. }

Very different is the Arthropod series, including Crustaceans, Insects, Spiders, etc., jointed animals like the

Annelid worms, but clad in firm armature of chitin and possessed of jointed appendages to which the name refers.

Crustacea. Crabs, crayfish, "water-fleas," etc.
Protracheata. *Peripatus*, probably a connecting-link between some worm-type and Insects.
Myriopoda. Centipedes and millipedes.
Insecta.
Arachnoidea. A miscellaneous class, including not only spiders and scorpions, but such divergent forms as mites, and probably the king-crab (*Limulus*), and the extinct Eurypterids and Trilobites.

Another branch of the genealogical tree, well-defined from the others, bears the shelled animals or MOLLUSCA. They are unsegmented, and without appendages, and probably derived from some worm type.

1. Lamellibranchiata. Bivalves.
2. Gasteropoda. Snails.
3. Cephalopoda. Cuttle-fishes.

And one or two smaller classes.

VERTEBRATE METAZOA.

Near the starting-point of this higher series, we must place two remarkable worm-like animals—*Balanoglossus* and *Cephalodiscus*. They have a dorsal nerve-cord as well as a ventral; in the anterior region of the body there is a slight supporting rod towards the dorsal surface; there are respiratory slits opening from the beginning of the food-canal to the exterior. In short, the Vertebrate affinities are well marked, and we shall at least emphasise the fact that there are no hard and fast lines of division if we place these two types at the beginning of the Chordate series. They form the class ENTEROPNEUSTA (gut-breathers), or HEMICHORDATA (half-chordate).

Stumbling at the threshold, as it were, are the sea-squirts or TUNICATA, or UROCHORDATA, which are distinctly Chordate when they are young, but usually degenerate in adolescence. The young have a dorsal nerve-cord, a dorsal axis, gill-slits, a ventral heart, a "brain-eye," but with the exception of a few like *Appendicularia*, which remain always young, the adults lose or disguise these Chordate characters.

A higher stage is represented by the lancelet (*Amphioxus*), sole type of the class CEPHALOCHORDATA. This animal is like a far-off prophecy of a fish, but is perhaps in some respects degenerate.

Approaching Fishes, but still far from them, are the Round-mouths or Marsipobranchs, CYCLOSTOMATA, *e.g.*, the hag (*Myxine*) and the lamprey (*Petromyzon*). They have no limbs, nor scales, nor true jaws, and their respiratory arrangements are peculiar.

At last we reach the Fishes (PISCES), finned, scaly, and jawed, including four great sets :—

1. Elasmobranchii. Gristly fishes, *e.g.*, Sharks and skates.
2. Ganoidei. Heavily armoured fishes, *e.g.*, Sturgeon and bony-pike.
3. Teleostei. Modern bony fishes, *e.g.*, Cod and salmon.
4. Dipnoi. Double-breathing Mud-fishes, in which the swim-bladder acts as a lung, and aids the gill. *Ceratodus*, *Protopterus*.

The double-breathing mud-fishes approach in some degree towards the next class—the AMPHIBIA, including, besides the extinct Labyrinthodonts, the following orders :—

1. Gymnophiona, earthworm-like subterranean amphibians, *e.g.*, *Cæcilia*.
2. Urodela, tailed animals, like the newts and salamanders.
3. Anura, tail-less forms, frogs and toads.

The Amphibians are soft-skinned, and have fingered limbs. In their youth they breathe by gills, and they may retain these throughout life, but whether they keep their gills or lose them, they always acquire true lungs. There are not many thoroughgoing distinctions between Amphibians and Fishes, and the two classes are ranked together as Ichthyopsida.

What the "worms" are among Invertebrates, the REPTILIA are among Vertebrates, an assemblage of classes. Unfortunately, however, most of these are extinct. In fact only five classes are now represented :—

1. Chelonia. Tortoises and turtles.
2. Proterosauria. *Sphenodon* or *Hatteria*, a remarkable New Zealand "lizard."
3. Lacertilia. Lizards.
4. Ophidia. Snakes.
5. Crocodilia. Crocodiles and Alligators.

Reptiles are scaly-skinned, they never breathe by gills, their heart is practically four-chambered, their embryos (like those of Birds and Mammals) have two birth-robes, an amnion and an allantois. The extinct Saurians are very numerous and diverse, and have affinities with Birds (and with Mammals?) as well as with the modern Reptiles.

There is no doubt that Birds (AVES) are linked to Reptiles, not only by resemblances in structure, but by extinct intermediate types. Divergent as they are in habit, they are ranked together as Sauropsida, in contrast to Fishes and Amphibians—Ichthyopsida—on the one hand, and to Mammals on the other. Feathers and wings, hot blood and airy bodies, characterise Birds. There are three great divisions :—

1. Saururæ. Reptile-like birds—the extinct *Archæopteryx*, with feathers and wings, but also with teeth and a reptile's tail.
2. Ratitæ. Flat-breasted running birds, *e.g.*, Ostrich and kiwi.
3. Carinatæ. Keel-breasted flying birds, *e.g.*, Pigeon and eagle.

Finally, we reach the MAMMALIA, superficially characterised by the hair on the skin, more profoundly by the milk which the mothers give to their young. There are three grades of mammalian excellence :—

1. Prototheria, Ornithodelphia, or Monotremes—the egg-laying duckmole (*Ornithorhynchus*) and *Echidna*.
2. Metatheria, Didelphia, or Marsupials—the prematurely-bearing, usually pouch-possessing kangaroos and their relatives.
3. Eutheria, Monodelphia, or Placentals—those in which there is a close (placental) union between the unborn embryo and its mother.

The placental Mammals include many orders :—

(*a*) The primitive sloths and ant-eaters—Edentata.
(*b*) The primitive dugong and manatee—Sirenia.
(*c*) The whales (Cetacea), the hoofed Ungulata (including elephants and *Hyrax*), and the Rodentia.
(*d*) The Insectivora, the bats (Cheiroptera), and the Carnivora.
(*e*) The Lemurs, and the Primates—the monkeys and man.
And extinct forms which link these sets together.

DIAGRAM I.

Chief Types of Structure.

C. Lowest is a single cell, an *Amœba*, with irregular outflowings of its living matter, with a nucleus (n) or cell-kernel, with two contractile vacuoles, and with some large granules in its cell-substance.

Bl. Next is a ball of cells, such as is formed when an ovum or egg-cell divides; or it may represent more diagrammatically one of the exceptional multicellular Protozoa.

G. Third is a gastrula, in section, showing two layers of cells, the outer ectoderm or epiblast, the inner endoderm or hypoblast, and the central cavity.

Next lies an unsegmented worm, with a simple blind gut, with an anterior patch of nerve-cells from which lateral nerve-cords run fore and aft.

Above this there is a diagram of a segmented worm, showing a food-canal (with a darkened mid-gut), a ventral nerve-cord with nerve-centres or ganglia in each segment, and a dorsal brain. There are also simple feet.

To the right side is a diagram of a starfish, in which the radiating nervous system is emphasised.

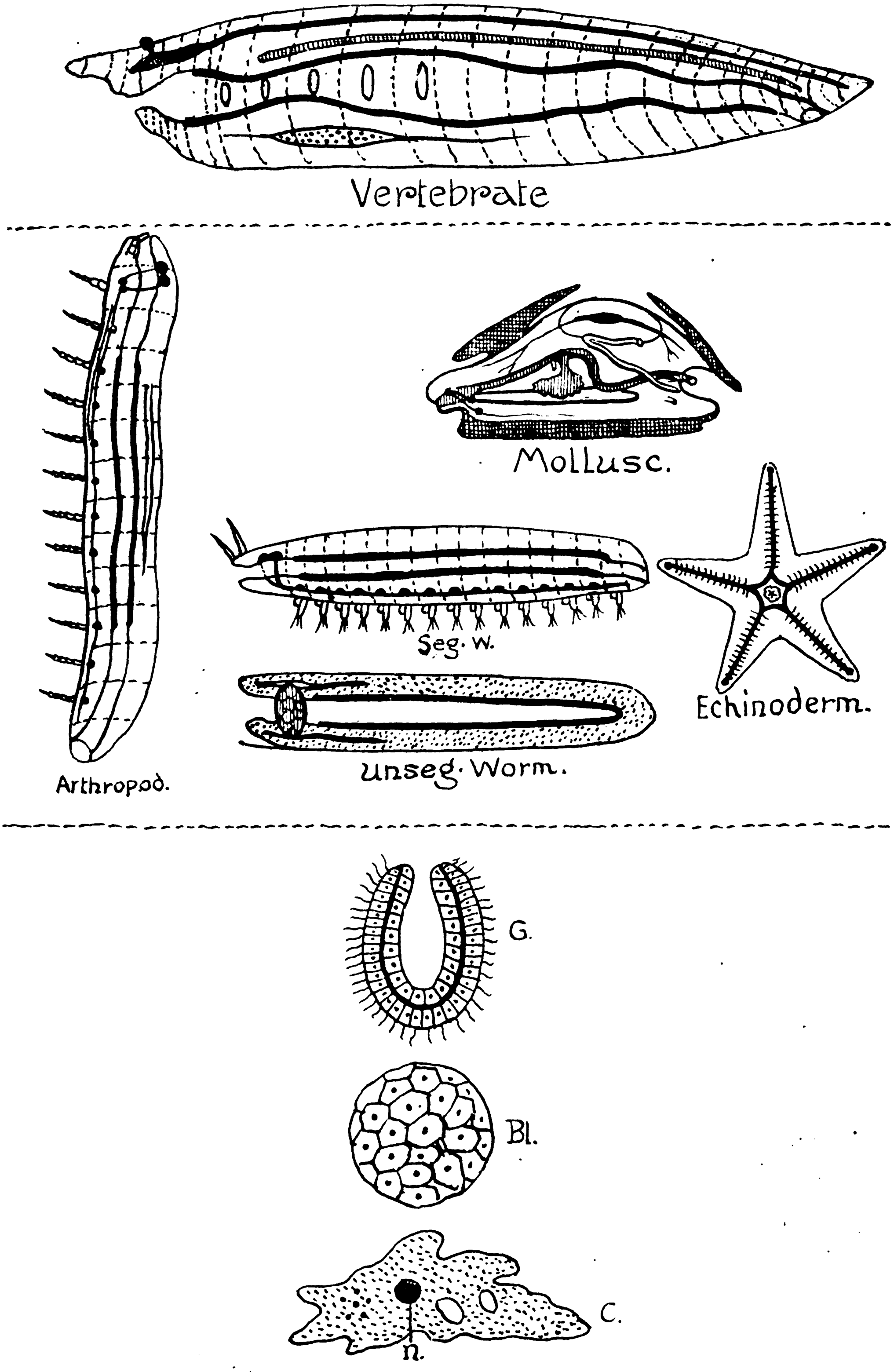
To the left side is an Arthropod, *e.g.*, a Myriopod, with jointed legs, a dorsal heart, ventral nerve-cord, dark mid-gut, etc.

To the right again is a rough copy of Ray Lankester's ideal Mollusc, showing the dorsal heart, the ventral "foot," the coiling food-canal, and other structures which can be readily identified from the chapter on Molluscs.

Highest is a very diagrammatic ideal vertebrate, showing the dorsal nervous system, the subjacent notochord, the gut with gill-slits, the ventral heart, and the segments.

Diagram I.

Chief Types of Structure.



METAZOA CHORDATA.

MAMMALIA.	Eutheria. Placentals. Metatheria. Marsupials. Non-placental. Prototheria. Monotremes. Oviparous.	Mammalia.	Gnathostomata (*i.e.*, jawed).	Craniota (with skulls).
AVES.	Carinatæ. Keeled flying birds. Ratitæ. Keel-less running birds. Saururæ. Extinct reptile-like birds.	Sauropsida.		
REPTILIA.	Crocodilia. Crocodiles and alligators. Ophidia. Snakes. Lacertilia. Lizards. Proterosauria. *Sphenodon.* Chelonia. Tortoises and turtles.			
AMPHIBIA.	Anura. Tail-less frogs and toads. Urodela. Tailed newts. Gymnophiona, *e.g.*, *Cæcilia.* Labyrinthodonts and other extinct amphibians.	Ichthyopsida.		
PISCES.	Dipnoi. Mud-fishes. Teleostei. Bony fishes. Ganoidei, *e.g.*, Sturgeon. Elasmobranchii. Cartilaginous fishes.			
CYCLOSTOMATA.	Hagfish (*Myxine*), and Lamprey (*Petromyzon*).			
CEPHALOCHORDATA.	*Amphioxus.*			Acrania (skull-less).
UROCHORDATA.	Tunicates.			
HEMICHORDATA.	*Balanoglossus* and *Cephalodiscus.*			

METAZOA NON-CHORDATA.

MOLLUSCA.	Cephalopoda. Cuttle-fishes. Gasteropoda. Snails. Lamellibranchiata. Bivalves.	
ARTHROPODA.	Arachnoidea. Spiders, scorpions, mites. Insecta. Myriopoda. Centipedes and millipedes. Protracheata. *Peripatus.* Crustacea.	
ECHINODERMATA.	Crinoidea. Feather-stars. (Cystoids and Blastoids, extinct.) Ophiuroidea. Brittle-stars. Asteroidea. Star-fish. Echinoidea. Sea-urchins. Holothuroidea. Sea-cucumbers.	
"WORMS."	Brachiopoda. Lamp-shells. Polyzoa, *e.g.*, Sea-mat (*Flustra*). Sipunculoidea, *e.g.*, *Sipunculus.*	
	Chætopoda. Bristle-footed worms. Discophora. Leeches.	Annelids.
	Nematoda. Thread-worms. Nemertea. Ribbon-worms.	
	Cestoda. Tape-worms. Trematoda. Flukes. Turbellaria. Planarians.	Plathelminthes.
CŒLENTERATA.	Ctenophora, *e.g.*, *Beroe.* Scyphozoa. Jellyfish and sea-anemones. Hydrozoa. Zoophytes and medusoids.	
PORIFERA.	Sponges.	

PROTOZOA.

INFUSORIA. RHIZOPODA. GREGARINIDA.
Simplest forms of animal life.

CHAPTER II.

THE FUNCTIONS OF ANIMALS.

(PHYSIOLOGY.)

MOST animals live a conscious and active life, busied with the search for food, the wooing of mates, the building of homes, and the tending of young. These, and other forms of activity, depend upon internal changes within the bodies of the animals. For all movements are due to the activity of contractile parts known as muscles, which are controlled by centres of thought and by impulse-conducting threads, in other words, by nerve-ganglia and nerve-fibres.

But as the work done means expenditure of energy, and is followed by muscular and nervous exhaustion, the necessity for fresh supplies of energy is obvious. This recuperation is obtained from food, but before this can restore the exhausted parts to their normal state, or keep them from becoming, in any marked degree, exhausted, it must be rendered soluble, diffused throughout the body, and so chemically altered that it is readily incorporated into the animal's substance.

We may say then that there are two master-activities in the animal body, those of muscular and those of nervous parts, to which the other internal activities are subsidiary conditions, turning food into blood and thus repairing the waste of matter and energy, keeping up the supply of oxygen and the warmth of the body, sifting out and removing waste-products.

Besides the more or less constantly recurrent activities or functions, which may be summed up under the general term "metabolism," or change, there are two other processes which should be ranked on a different platform,

—growth and reproduction. When income exceeds expenditure in the life of a young animal, growth goes on, and the inherited qualities of the organism are more and more perfectly unfolded. At the limit of growth, when the animal has reached "maturity," it normally reproduces, that is to say, liberates parts of itself which give rise to new individuals.

Division of Labour.—In the first chapter of the fourth edition of Prof. Foster's *Text Book of Physiology*, you will find a graphic account of the activities of the *Amœba*. It moves by contracting its living substance, it draws back sensitively from hurtful influences, it engulfs and digests food, it gets rid of waste, and it absorbs the oxygen, without which its living matter cannot continue active or indeed alive. For activity means, in part, an oxidation, a combustion of material, and respiration in plants and animals alike essentially consists in absorbing oxygen, and in liberating the carbonic acid gas which is one of the waste products both of life and burning.

But the physiological interest of the *Amœba*, and minute animals like it, is that all the activities occur within the compass of a unit mass of a living matter,—a single cell. There is no division of labour, there are as yet no parts.

In all other animals, from sponges onwards, there is a "body" consisting of hundreds of unit masses or cells. It is impossible for these to remain the same, for some are internal and others external, nor would it be well for the organism that all its units should persist with the primitive and many-sided qualities of Amœbæ. Division of labour, consequent on diversity of conditions, is thus established in the organism. In some cells one kind of activity predominates, in others a second, in others a third. And this division of labour is followed by that complication of structure which we call differentiation.

Thus, in the fresh-water *Hydra*, which is one of the simplest many-celled animals, the units are arranged in two layers, and form a tubular body. Those of the outer layer are protective, sensitive, and muscular; those of the inner layer absorb and digest the food, and are also muscular.

In worms and higher organisms, there is a middle layer

in addition to the other two, and this middle layer becomes, for instance, predominantly muscular. Moreover, the units or cells are not only arranged in strands or tissues, each with a predominant function, but they become compacted into well defined parts or organs.

There is no idea more important in physiology than that of the division of labour, therefore let me state it once more. The Amœbæ, and other single-celled organisms, discharge all the functions (*a*, *b*, *c*, *d*, *e*, *f*) within a single cell. Structurally these animals are very simple, but the physiology of a completely functional cell must be very complex. In a comparatively simple many-celled organism, like a *Hydra*, the outer cells discharge several functions (say *a*, *b*, *c*, *d*), and the inner cells discharge several functions, partly the same and partly different (say *c*, *d*, *e*, *f*). The more complex the animal becomes, the more restricted are the functions of its individual cells; different sets retain the activities represented by *a*, *b*, or *c*, *d*, or *e*, *f*. Thus a muscle-cell is predominantly contractile, a sense-cell predominantly sensitive, a ganglion-cell receives, regulates, and originates nervous impulses, a red blood-cell carries oxygen from the surface to the innermost recesses of the tissues. None the less should we remember that each cell remains a living unit, and that, in addition to its principal activity, it usually retains others of a subsidiary character. It is a certain conclusion, alike of common observation and the most complete physiological analysis, that one living structure may have a plurality of functions.

History.—Physiologists, or those who study the activities of organisms and of their parts, were at first content to speak of these as the result of "animal and vital spirits," of moods and temperaments. We ought not to do so now until we have done our utmost to explain the activities in lower terms.

Stimulated, however, by the anatomists' disclosure of organs, the physiologists soon began to explain the organism as a complex engine of many parts. The muscles were recognised as the mechanisms which produced movement, the heart pumped the blood through the body, the brain was the seat of thought, and so on. This was an exceedingly necessary and natural step in analysis. Nor has

it yet been thoroughly taken in every case, for there are many organs, especially in backboneless animals, about whose predominant use we are very uncertain. But the physiologists of this school sometimes finished their work too quickly. That the liver was an organ for secreting bile was for a long time deemed a completely satisfactory statement, until it began to be seen that this organ is the seat of many other activities. Moreover, some thought that it was possible to deduce the function of an organ from the nature of its structure, as one would infer the use of a piston from its shape. To a certain extent we can explain the functions of an organ in terms of its visible structure, as when we shew how an image is formed on the retina of the eye. But we cannot, in terms of visible structure, explain another function of the eye—that of distinguishing the "colours" of things. In short, it must be clearly understood that each organ is far more than a piece of mechanism in a living engine,—that it is a complicated factory of living units, each with subtle and manifold powers.

In 1801, Bichât analysed the animal body into its component tissues or living strands—muscular, nervous, glandular, etc., and being a physiologist as well as an anatomist, tried to explain the activities of the organism in terms of the contractile, irritable, secretory, or other properties of its tissues. This was a further step in the analysis, and one of great importance.

About forty years later, however, it began to be recognised that the body was a great city of cells, each with a life of its own. The functions were not merely the activities of organs of various construction, or of tissues with various properties, they were the results of the life of the component units or cells.

Finally, in those last days the physiologists have touched the bottom in their analysis, for they are striving with might and main to discover the physical and chemical changes associated with the living stuff or protoplasm itself. These are obviously at the foundation of the whole matter.

A Sketch of the chief Functions in a higher Organism, such as Man.

We have seen that the power of movement is one of the chief characteristics of animals, but movement implies a source of energy. This, as is well known, is to be found in food; therefore we shall begin by studying the way in which food is prepared, so that the tissues of the body may absorb it.

After the solid food is taken into the mouth, it is cut into small pieces by the teeth, and moistened by saliva, so that it may be easily swallowed. But the saliva has a further function. We eat, in one form or another, considerable quantities of starch; but starch occurs as grains of a size that would make it of little use as food if it were not digested. Digestion implies physical and chemical changes which make the solid food-materials soluble, and the saliva has this effect upon the starch, it transforms it into an easily soluble sugar. It does this by means of a ferment, which, however, has never been isolated. The saliva is prepared in three pairs of glands, situated near the mouth. The digestion of starch in the mouth is by no means complete, because it stays there too short a time; but if a quantity of starch be boiled, so as to soften and break the walls of resistent cellulose that surround the starch granules, and a little saliva added to the mixture, it becomes thin and transparent, and the presence of sugar can be proved by the ordinary chemical tests. In a few minutes a considerable quantity of starch will be transformed into sugar. To what is this power of the saliva due? If it be filtered, so as to get rid of the mucus and other matters, and mixed with fifteen times its volume of alcohol, a precipitate is formed, which contains all the more complex substances or proteids. In time these coagulate, and become insoluble in water; but if the precipitate be now washed, the fluid will be found very active in its starch-transforming powers. So it is neither in the mucus nor in the proteids that the powers of the saliva reside. The active substance is not yet known, it has never been isolated, and can be recognised only by its powers. It is called ptyalin; its peculiarities are:—

(1) its inappreciable quantity;
(2) the dependence of its activity upon temperature, it being most active at about 35° C, and entirely destroyed by boiling;
(3) the fact that it apparently undergoes no change itself while active, since a very small quantity will transform an unlimited amount of starch if the sugar be removed as it is formed.

It therefore belongs to the class of bodies known to chemists as ferments, and as there are many such active within the body, we have dwelt at some length upon the general properties of this, the first one we meet with.

The food cut into pieces by the teeth, moistened, and in part changed by the saliva, is swallowed, and passes into the stomach, where it is mixed with a fluid, the gastric juice, which is manufactured in glands situated in the walls of the stomach. The walls are muscular, and their contractions churn and mix the food with the juice. This juice has no effect upon the starch, and little upon the fat of the food; its important action is upon the more complex proteids, which, being changed and dissolved, are rendered capable of being absorbed into the blood. There is in gastric juice a quantity of free hydrochloric acid, and a ferment called pepsin, analogous in its conduct and dependence on temperature to the ptyalin of the saliva. The acid and the ferment act together in the process of digestion, neither of them by itself has any effect, but the acid stops the action of the ptyalin upon starch.

[The action of the gastric juice upon milk is peculiar; it is first curdled, and then part is digested. Milk contains fat, sugar, salts, and proteids, especially one called casein; the curdling consists in the precipitation of this casein, and is not due to the acidity of the juice, for it takes place when the acid is neutralised, but is caused by a ferment called rennet.]

There is now in the stomach a mixture of solid and dissolved foods; those in solution are the proteids digested by the gastric juice, and that portion of sugar transformed by the saliva, besides, of course, any food-stuffs that may have been taken as liquids. The solids are the fats and the rest of the starch, though the fats are partially melted by the

high temperature, and form an imperfect emulsion. The stomach is now gradually emptied, partly by the escape of the semi-digested food through the lower opening, and partly by the absorption of dissolved parts into the blood. The semi-digested food, as it passes out of the stomach into the small intestine, is called chyme; when it reaches the opening into the intestine of the bile duct, and of the duct from the pancreas, a flow of bile and pancreatic juice takes place. These being both alkaline tend to neutralise the acidity of the chyme, and their other uses are as follows:—The conversion of starch into sugar is recommenced by a ferment in the pancreatic juice; by another ferment the fats are emulsified, that is, the drops become extremely small, and so can be absorbed; a third ferment splits the fats into fatty acids and glycerine. The acids are converted into soaps to a certain extent by the alkaline contents of the intestine, this favours the process of emulsification in which the bile also takes part. On proteids the action of the pancreatic juice is similar to that of the gastric juice; the ferment in this case is called trypsin. It acts in a neutral fluid, whereas pepsin requires the presence of hydrochloric acid. The pancreatic juice is therefore a very powerful one, repeating with some additions all the digestive processes of the other glands:—

(1) transforming starch into sugar;
(2) transforming proteids into soluble peptones;
(3) emulsifying fat;
(4) splitting fats into fatty acids and glycerine.

The powers of bile may be summarised as:—

(1) in some animals, a slight power of converting starch into sugar;
(2) by its alkalinity, preparing the way for the action of trypsin;
(3) a slight solvent action on fats, a slight emulsifying power, and the formation of soaps with fatty acids;
(4) in affecting cell-membranes so that they allow the passage of small drops of fat and oil;
(5) various antiseptic qualities.

In addition to the liver and pancreas, there are on the walls of the small intestine a great number of small glands

which secrete a juice known as the succus entericus, which probably seconds the pancreatic juice. The digested material is in part absorbed into the blood, and the mass of food still being digested is passed along the small intestine by means of the muscular contractions of the walls, known as peristaltic action. It reaches the large intestine, and its reaction is now distinctly acid by reason of the acid fermentation of the contents. The walls of the large intestine contain glands similar to those of the small intestine, and the digestive processes are completed, while absorption also goes on; so that by the time the mass has reached the rectum, it is semi-solid, and is known as fæces. These contain all the indigestible and undigested remnants of the food and the useless products of the chemical digestive processes.

So far, we have dealt with the general process of digestion, that is, the preparing the food for absorption into the blood; we shall now sketch the manner of absorption, and the treatment of the absorbed matters after they have reached the blood. Absorption begins in the stomach by direct osmosis into the capillaries or fine branches of blood-vessels in its walls, and a similar absorption, especially of water, takes place along the whole of the digestive tract. But lining the intestines there are special hair-like projections called villi; they contain capillaries belonging to the portal system (blood-vessels going to the liver), and small vessels known as lacteals connected with lymph spaces in the wall of the intestine. The lacteals lead into a longitudinal lymph vessel or thoracic duct, which enters one of the veins of the neck. In the centre of each villus the lacteals end in blind spaces; round them is a netted tissue with many lymph spaces; round these a capillary network of blood-vessels, and also some muscular fibres used for shortening and emptying the villus. The whole is enclosed in a sheath of fine skin or epithelium. The finely divided fat passes through this epithelium into the lymph spaces of the netted tissue, then into the lacteals, and so to the thoracic duct.

The villus empties itself by the contraction of its muscular fibres; on the relaxation of these, the fat is prevented from returning by valves, while the expansion sucks the fat from the netted tissue. The thoracic

duct, being part of the lymphatic system, contains some lymph (which may be roughly described as blood *minus* its red corpuscles), while the chyle which forms the greater part of the content of the duct is lymph *plus* the finely divided fat absorbed from the intestine. Every movement of the body aids the further progress of the chyle by causing alterations of pressure, while flow is only permitted in one direction owing to the great number of valves. The thoracic duct, finally, opens into the junction of the left jugular and left subclavian veins at the root of the neck.

The contents of the duct of a fasting animal are clear; after a meal they become milky; the change is due to the matters discharged into it by the lacteals. It is probable that nearly all the fat of a meal is absorbed from the intestines by the lacteals, but it is not certain in what measure, if at all, this is true of the other dissolved food-stuffs; the greater part certainly passes into the capillaries of the portal system, which are contained in each villus. The peptone or digested proteid, as it passes through the cells of the villi, is changed into other proteids nearly related to those of the blood, for no peptone is found in the portal vein.

We now know the fate of the fats, and of the proteids of the food, and the manner in which they pass into the blood; but we must follow the starchy material, or carbohydrates, a little further. The starch, we know, is converted into sugar, and this, with the sugar of the food, passes into the capillaries of the villi, and is carried to the liver. During digestion there is an increase of sugar in the blood vessel going to the liver from the intestine, that is, in the portal vein, but no increase in the vessel leaving the liver. The increase must therefore be retained in that organ, and we recognise as one of the functions of the liver, the regulation of the amount of sugar in the blood. There is no special organ for the regulation of the amount of fat; the drops pass through the capillary walls, and are retained in the connective tissues.

We must remember that all the products of digestion, except the fat, pass through the liver which receives everything before it is allowed to pass into the blood of the system. Thus many poisons, especially metals, are arrested by the liver, and many substances which result from digestive processes and would be harmful, are altered into harmless compounds by it. The excess of sugar, we have already

noted, is stored in the liver. It is converted there into a substance called glycogen which can be readily retransformed into sugar according to the needs of the system. Glycogen is stored in the muscles also, and is the material chiefly useful as the fuel for the supply of muscular energy and of the warmth of the body. Thus, if an animal be subjected to a low temperature, the glycogen of the liver disappears just as it does during the performance of muscular work.

There is another most important food-stuff to be noticed. This is the oxygen which is absorbed from the air by the lungs. The lungs we may picture as a sort of elastic sponge-work of air chambers, with innumerable blood capillaries in the walls, enclosed in an air-tight box, the chest, the size of which constantly and rhythmically varies. When we take in a breath the size of the chest is increased, the air pressure within is lowered, and the air from without rushes down the windpipe until the pressure is equalised. The oxygen of this air combines with a substance called hæmoglobin, contained in the red corpuscles of the blood, and is thus carried to all parts of the body. The protoplasm of the tissues having a stronger affinity for oxygen than has the hæmoglobin, takes as much as it requires. The carbonic acid gas formed as a waste-product is absorbed by the serum of the blood, and so in time reaches the lungs. But as the partial pressure of the carbonic acid in the air is lower than it is in the serum, the gas escapes from the latter into the air chambers of the lungs. When the size of the chest is decreased, the pressure is increased, and the gas escapes by the mouth until the pressure is equalised. By the constant repetition of the breathing movements, oxygen is constantly being taken in, and carried to the tissues which are in a marvellous way "hungry" for it, while the waste carbonic acid gas is as constantly being removed.

Thus the gaseous waste of animal life is got rid of. But there is much waste resulting from tissue changes, which is not gaseous. It is cast into the blood stream by the tissues, and has to be got rid of in some way. This is effected by the kidneys, which are really filters introduced into the blood stream for the purpose of purifying it. But they are the most marvellous filters imaginable, and give us a good example of the intricacy of life processes. For the

kidneys not only cast out of the blood all the waste-products that result from the metabolism of proteids and contain nitrogen; but they maintain the composition of the blood at its normal, rejecting any stuffs that vary from that normal, either qualitatively or quantitatively, doing this work according to laws quite different from the simple ones of diffusion or solubility; thus, sugar and urea are about equally soluble, and yet the sugar is kept in the body, while the urea is cast out. Even substances as insoluble as resins are removed from the blood by the living cells of the kidneys.

A considerable quantity of water, and traces of salts, fats, etc., leave the body by the skin, but its chief use is to protect, and to regulate the temperature by variations in the size of its blood-vessels.

This completes our sketch of the process by which the food becomes available for the organism as fuel for the maintenance of its life energies, and of the removal of the waste-products which are formed as the ashes of its life. The purpose of the preceding sketch is merely to give a general knowledge of the functions of those organs which will be discovered in the dissection of animal types, and of which the student beginning the study of Zoology is generally ignorant. Little need be said, therefore, of the muscles, for every one knows that by contracting they produce movements of the body or of its parts. The contraction of a muscle-cell or fibre involves, (1) a visible change of form, (2) the liberation of heat, and the discharge of water and carbon dioxide, which show that a chemical change takes place within, and (3) certain subtle electrical changes, the meaning of which we do not clearly understand. As to the rapid chemical change, the results of which are known, it is plausible to suppose that there is within the muscle-fibre and under the regulation of its living matter, an encounter between oxygen on the one hand, and some readily oxidisable material on the other. The chemical energy of this encounter is transformed into heat and into the kinetic energy bf muscle-movement by which work is done.

Nor shall we discuss the nervous system, because to treat it even in the simplest way would occupy a great deal of space, and because every one knows in a general way that ganglia or collections of ganglia, such as our brain, are

concerned with the translation of sensations from the outer world into perceptions, and with the origination of movements in accordance with those perceptions; and that nerve-fibres are used as the paths by which sensations are conducted to nerve-centres, and by which the resulting commands are conducted to the various parts of the body. For the same reason we give no account of the sense-organs, for every one knows the purpose of an eye or an ear, and in noting structure and position is not troubled with doubts as to function, as often occurs when the internal organs are being dissected out.

In conclusion, it will perhaps be well to remark, that when in the course of further studies the student meets with organs which are called by the same name as those found in man or in Mammals, as for example, the "liver" of the Molluscs, he must be careful not to suppose that the function of such a "liver" is the same as in Mammals, for comparatively little investigation into the physiology of the lower types of animal life has as yet been made. At the same time he must clearly recognise that the great internal activities are in a general way the same in all animals: thus, respiration, whether accomplished by skin, or gills, or air-tubes, or lungs, by help of the red pigment (hæmoglobin) of the blood, or of some pigment which is not red, or occurring without the presence of any blood at all, always means that oxygen is absorbed almost like a kind of food by the tissues, and that the carbonic acid gas which results from the oxidation of part of the material of the tissues is removed.

Modern Conception of Protoplasm.—The activities of animals are ultimately due to physical and chemical changes associated with the living matter or protoplasm. This is a mere truism. We do not know the nature of this living matter, in fact our most certain knowledge of it is that in our brains its activity is expressed as thought.

But though we cannot analyse living matter, nor thoroughly explain the changes by which the material of the body breaks down or is built up, we can trace, by chemical analysis, how food passes through various transformations till it becomes a useable part of the living body, and we can also catch some of the waste-products formed when muscles or other parts are active.

Apart from any theory, it is certain that waste-products are formed when work is done, and that living animals have a marvellous power of rapid repair, of ceaselessly changing, and yet remaining more or less the same. Theory begins when we attempt to make the general idea of waste and repair more precise. In the study of "protoplasm," both morphologist and physiologist have reached their strict limits. Further analysis becomes physical and chemical, and ends in the confession that protoplasm is a marvellous form of matter in motion or a subtle kind of motion of which we can form only a very vague conception.

What is known in regard to the structure of protoplasm does not help the physiologist very much. As we shall afterwards see, the microscopists discover an intricate network which pervades each unit of living matter, but no physiologist dreams of explaining the life of a cell in terms of its microscopically visible structure. Yet, as Professor Burdon Sanderson says, "we still hold to the fundamental principle that living matter acts by virtue of its structure, provided the term structure be used in a sense which carries it beyond the limits of anatomical investigation, *i.e.*, beyond the knowledge which can be attained either by the scalpel or the microscope." But in the end this means that living matter acts in virtue of its peculiar qualities, its characteristic motion, of which we can form only a hypothetical conception, and can give no scientific explanation.

One general idea, however, the study of structure has suggested, which the conclusions of physiologists corroborate. This idea is, that a cell consists of a relatively stable living framework and of a changeful content enclosed by it.

Now, many physiologists regard the framework as the genuine living protoplasm, and the contents as the material upon which it acts. "The framework is the acting part, which lives, and is stable; the content is the acted-on part, which has never lived, and is labile, that is, in a state of metabolism or chemical transformation." This view naturally leads those who adopt it to regard protoplasm as a sort of ferment acting on less complex material which is brought to it and which forms the really changeful part of each cell. You will remember that the strange characteristic of a ferment is, that it can act on other substances without being itself

affected by the changes which it produces, and that it can go on doing so continuously, with a power which has no direct relation to its amount. In many ways, therefore, living matter resembles a ferment.

Somewhat different, however, is another idea, that the protoplasm is itself the seat of constant change, that it is constantly being unmade and remade. On the one hand, more or less crude food passes into life by an ascending series of assimilative or constructive chemical changes with each of which the material becomes molecularly more complex and more unstable. On the other hand, the protoplasm, as it becomes active or a source of energy, breaks down in a descending series of disruptive or destructive chemical changes ending in waste products.

The former view, which considers protoplasm as a sort of ferment, restricts the metabolism to the material on which the protoplasm acts. The second view regards protoplasm as the climax or central term of the constructive and disruptive metabolism.

Anabolism and Katabolism.—All physiologists are agreed that in life there is a twofold process of waste and repair, of discharge and restitution, of activity and recuperative rest. But there is no certainty as to the precise nature of this twofold process.

In your future physiological studies, you will have to consider the power that our eyes have of appreciating those different kinds of light which give rise to sensations of colour. It was in studying these that Professor Hering was led to an interesting theory of living matter. He supposes that there exist in or about the retina three different "visual substances," which we may call A, B, C. He supposes that each of these is continually undergoing one of two kinds of metabolism. It is either being built up by assimilation, or it is being broken down in disassimilation. He supposes that each of these substances is affected by two kinds of light, and that these two kinds of light have opposite influences on the metabolism of the substance. When we have a sensation of white, or of red, or of yellow, it is supposed that in one of the three kinds of visual substance disassimilation is preponderant. When we have a sensation of black, or of green, or of blue, it is supposed that in one of the three kinds of visual substances assimilation is preponderant. Excess of disassimilation in A, gives us the sensation of white ; excess of assimilation of A, gives us the sensation of black ; and similarly with red and green for B, with yellow and blue for C.

But generalising from his studies on colour sensation, Hering was led to regard all life as an alternation of two kinds of activity, both induced

by stimulus, the one tending to storage, construction, assimilation of material, the other tending to explosion, disruption, disassimilation. Both processes are, according to Hering, activities ; both are dependent upon stimulus ; they differ, however, in direction and results.

In your future physiological studies, you will also learn of the paths or channels by which the brain sends its mysterious commands to the various parts of the body. You will learn that some of these bear impulses to activity, while others convey commands which send the affected part to rest.

It was in studying and greatly elucidating these interesting facts, that Professor Gaskell was led to a theory of vital action somewhat different from that of Hering.

Gaskell believes that life means an alternation of two processes, one of them a running down or disruption (katabolism), the other a winding up or construction (anabolism). The disruptive or katabolic process in which energy is discharged, takes place occasionally and in obedience to stimulus ; the constructive or anabolic process of restitution goes on constantly and of itself, *i.e.*, without the necessity of stimulus. Thus Gaskell's theory suggests an alternation of activity and rest, of stimulated disruption and self-regulative construction, while Hering's theory suggests an alternation of two antagonistic kinds of activity, assimilation and disassimilation, both requiring stimulus. The student will find the theories, which I have briefly noticed, discussed in Professor M. Foster's article PHYSIOLOGY, in the *Encyclopædia Britannica*, and in an address by Professor Burdon Sanderson (British Association Reports, 1889, and also published in *Nature*, September 1889).

CHAPTER III.

THE ELEMENTS OF STRUCTURE.

(MORPHOLOGY.)

ANIMALS may be studied alive or dead, in regard to their activities or in regard to their parts. We may ask how they live, or what they are made of; we may investigate their functions or their structure. The study of life, activity, function, is physiology; the study of parts, architecture, structure, is morphology.

The first task of the morphologist is to describe structure (descriptive anatomy); the second is to compare the parts of one animal with those of another, discovering structural resemblances or homologies (comparative anatomy); the third is to generalise, to formulate the "principles of morphology" or the laws of vital architecture. But in none of his tasks, least of all in the last, can he help being or trying to be a physiologist and an evolutionist also.

But just as the physiologist may investigate life or activity at different levels, passing from his study of the animal as a unity with habits and temperaments, to consider it as an engine of organs, a web of tissues, a city of cells, and a whirlpool of living matter; so the morphologist has to investigate the form of the whole animal, then in succession its organs, their component tissues, their component cells, and finally, the structure of protoplasm itself. The tasks of morphology and of physiology are parallel.

Morphology thus includes not only the description of external form, not only the anatomy of organs, but also that minute anatomy of tissues and cells and protoplasm which we call histology. Moreover, there is no real difference between studying fossil animals which died and were buried

countless years ago, and dissecting a modern frog. The anatomical palæontologist is also a student of morphology. Finally, as the greater part of embryology consists in studying the anatomy and histology of an organism at various stages of its development, the work of the embryologist is also in the main morphological, though of course he ought also to inform us, if he can, about the physiology of development.

Morphology, then, may be defined as "the study of all the statical aspects of organisms," in contrast to physiology which is concerned with their vital dynamics. In this chapter, we shall follow the historical development of morphology, and work from the outside inwards in deeper and deeper analysis.

I. External Form.

I have not to speak of the beautiful shapes of animals, nor of the manner in which form is adapted, for instance in fishes and birds, to the conditions of life; I call your attention to more commonplace but essential facts. Sponges and Stinging-animals have an entirely different symmetry from all other Metazoa. For while most many-celled animals pass in early life through an embryonic stage called the *gastrula*—an oval or thimble-shaped sac of two layers of cells—the Sponges and Cœlenterates alone preserve the symmetry of this stage. In a simple tubular sponge, in *Hydra*, or in a sea-anemone, the oral-aboral or long axis extending from the mouth to the other pole of the body, corresponds to the long axis of the gastrula. Round this axis, moreover, the simple sponge and almost every cœlenterate is radially symmetrical. It is the same all round. In other animals, however, the long axis of the body, the oral-aboral axis, say of an earthworm or a fish, does *not* correspond to the longitudinal (but rather to the transverse) axis of the gastrula. Moreover, these animals are bilaterally not radially symmetrical. They have a head and a tail, and two sides. Some worm-like animals seem to have begun the profitable habit of moving head foremost; had they not done so, we should never have known our right hand from our left. The

radiate symmetry of star-fishes and sea-urchins, may occur to you as an exception, but it is more apparent than real, and, as their bilateral embryos show, it is secondarily derived. Another very important fact in symmetry is the formation of successive segments, as in Annelids and Arthropods. In the course of our systematic survey, we shall refer to other questions of symmetry, such as the marked lop-sidedness in snails, and the contrast between backboneless and backboned animals, according to which Vertebrates may be thought of as arising from worms turned upside down, from inverted Invertebrates.

II. Organs.

We usually give this name to any well-defined part of an animal, such as limb or liver, heart or brain. The word suggests the idea of a piece of mechanism, but the animal is more than a complex engine, and many "organs" have several different kinds of activities to which their structure gives no clue.

Differentiation and Integration.—When we review the animal series, or study the development of an individual, we see that organs appear gradually. The gastrula cavity—the future stomach, etc.,—is the first acquisition, but some would make out that it was primitively a brood-chamber. To begin with, it is a simple sac, but it soon becomes complicated by digestive and other outgrowths. The progress of the individual, and of the race, is from simplicity to complexity. When we think over the animal series we also notice that before definite nervous organs appear there is diffuse sensitiveness, before definite muscular organs appear there is diffuse contractility, and so on. In other words, the attainment of organs means specialisation of parts, or concentration of functions in particular areas of the body.

Contrast a frog with *Hydra*, and one of the great facts about the evolution of organs is illustrated. Among the living units which make up a frog, there is much more division of labour than there is among those of *Hydra*. An excised representative sample of *Hydra* will reproduce the

whole, but you cannot perform this experiment with the frog. Now, the structural result of physiological division of labour is differentiation. The animal, or part of it, becomes more complex, more heterogeneous.

Contrast a bird and a sponge this time, and another great fact about the evolution of organs is illustrated. Every one feels that the bird is more of a unity than a sponge; its parts are more closely knit together and more adequately subordinated to the life of the whole. We call this kind of progress, integration. Differentiation involves the acquisition of new parts and powers, these are consolidated and harmonised as the animal becomes more "integrated."

Correlation of Organs.—It is of the very nature of an organism that its parts should be mutually dependent. The organs are all partners in the business of life, and, if one member suffer, others also are affected. This is especially true of certain organs which have developed and evolved together, and are knit by close physiological bonds. Thus the blood-vascular and the respiratory systems, the muscular and the skeletal systems, the brain and the sense-organs, are very closely united, and we say that they are *correlated.* A variation, for better or worse, in one system often brings about a correlated variation in another, but sometimes we cannot trace the connection.

Homologous Organs.—Organs which arise from the same primitive layer of the embryo (see next Chapter), have something in common. But when a number of organs arise in the same way, from the same embryonic material, and are at first fashioned on the same plan, they have still more in common. Nor will this fundamental sameness be affected though the final shape and use of the various organs be very different. We call organs which are thus structurally and developmentally similar, *homologous.* It obviously makes no difference whether they belong to the same or to different animals; the nineteen pairs of appendages on a crayfish are all homologous; the three pairs of "jaws" in an insect are homologous with the insect's legs; and it is also true that the fore-leg of a frog, the wing of a bird, the flipper of a whale, the arm of a man, are all homologous. But the wing of a bird and the wing of an insect are not really similar; though they are both organs of flight, they are only *analogous.*

Similarly, gills are analogous but not homologous with lungs. Yet two organs may be both homologous and analogous, *e.g.*, the wing of a bird and the wing of a bat, for both are fore-limbs, and both are organs of flight.

Change of Function.—Division of labour involves restriction of functions in the several parts of an animal, and no higher Metazoa could have arisen if all the cells had remained with the many-sided qualities of Amœbæ. Yet we must avoid thinking about organs as if they were necessarily active in one way only. For many organs, *e.g.*, the liver, have several very distinct functions, and we know how wondrously diverse are the activities in our brains. In addition to the main function of an organ there are often secondary functions: thus, the wings of an insect are respiratory as well as locomotor, and part of the food-canal of Tunicates and *Amphioxus* is almost wholly subservient to respiration. Moreover, in organs which are not very highly specialised, it seems as if the component elements retained a considerable degree of individuality, so that in course of time what was a secondary function may become the primary one. Thus Dohrn, who has especially emphasised this idea of function-change, says, "Every function is the resultant of several components, of which one is the chief or primary function, while the others are subsidiary or secondary. The diminution of the chief function and the accession of a secondary function changes the total function; the secondary function becomes gradually the chief one; the result is the modification of the organ." Notice, in illustration, how the structure known as the allantois is an unimportant bladder in the frog, while in Birds and Reptiles it forms a birth-robe (chiefly respiratory) around the embryo, and in most Mammals forms part of the placenta which effects nutritive connection between offspring and mother. The stalk of this allantois forms the urinary bladder of Mammals, and of those Reptiles which have one. In illustration it is sometimes said that the swim-bladders of Fishes, especially of the Dipnoi, represent the lungs of higher Vertebrates, but there are several objections to this statement.

"*Substitution of Organs.*"—The idea of several changes of function in the evolution of some organs, suggests another of not less importance which has recently been emphasised

by Kleinenberg. An illustration will explain it better than a concise statement. In the simplest Chordata, young Tunicates and *Amphioxus*, and in the early stages of all vertebrate embryos, the supporting skeleton is a dorsal rod or notochord, developed along the dorsal wall of the gut. In Vertebrates, from Fishes onwards, this embryonic axis is replaced by the vertebral column or backbone; it does not become, but is replaced by the backbone. It is a temporary structure, around which the vertebral column is constructed, as a tall chimney may be built around an internal scaffolding of wood. Yet, as we have said, it remains as the axial skeleton in *Amphioxus*, likewise in great part in hagfish and lamprey, but becomes less and less persistent in adult life, as its substitute, the backbone, develops more perfectly in Fishes and higher Vertebrates. Now, what is the relation between the notochord and its substitute the backbone, seeing that the former certainly does not become the latter? Kleinenberg's suggestion is that the notochord supplies the stimulus, the necessary condition, for the formation of the cartilaginous and eventually bony vertebral column. Of course, we require to know more about the way in which an old-fashioned structure may stimulate the growth of its future substitute, but the general idea of one organ leading on to another is clear and suggestive. It is consistent with the vague idea which we all have, that every stage in development supplies the necessary stimulus for the next step; moreover, it enables us to understand more clearly the persistence of new structures too incipient to be of use.

Rudimentary Organs.—In many animals there are structures which attain no complete development, which are rudimentary in comparison with those of related forms, and are retrogressive when compared with their promise in embryonic life. It is necessary to distinguish various kinds of "rudimentary structure." (*a*) As a pathological variation, probably due to some germinal defect, or to the inefficient nutrition of the embryo, the heart of an individual mammal is sometimes incompletely formed. Other organs may be similarly spoilt in the making. We may call these illustrations of *arrested development.* (*b*) Some animals lose, in the course of their life, some of the most promiseful characteristics of their larval life: thus parasitic Crustaceans at first free-living,

and sessile sea-squirts at first free-swimming, always undergo *degeneration*. The retrogression can be seen in each lifetime. But the little Kiwi of New Zealand, with mere apologies for wings, and many cave-fishes and cave-crustaceans with slight hints of eyes, illustrate degeneration which has taken such a hold of the animals that the young stages also are degenerate. The retrogression cannot be seen in each lifetime, evident as it is when we compare these degenerate forms with their ancestral ideal. (*c*) But by "rudimentary organs" we mean very often structures somewhat different, *e.g.*, the branchial or visceral clefts which persist in embryonic Reptiles, Birds, and Mammals, though they serve no obvious purpose, or the embryonic teeth of whalebone whales, of the duckmole, and of parrots. These are "vestigial structures," traces of ancestral history, and explicable on no other theory. The branchial clefts are used for respiration in all Vertebrates below Reptiles: the ancestors of whalebone whales, of the duckmole, of Birds, doubtless had functional teeth. In regard to these persistent vestigial structures, it must also be recognised that we are not warranted in calling them useless. Though they themselves serve no obvious purpose, they may be, as Kleinenberg suggests, the necessary conditions of some useful structure.

Classification of Organs.—We may arrange the various parts of the body physiologically, according to their share in the life. Thus, some parts have most to do with the *external* relations of the animals; such are the external appendages, locomotor, prehensile, food-receiving, protective, aggressive, and copulatory. Of *internal* parts, the skeletal structures are passive; the nervous, muscular, and glandular parts are active. The reproductive organs are distinct from all the rest. They are often called "gonads," and should never be called glands.

Another important classification of organs is embryological, *i.e.*, according to the embryonic layer from which the various parts arise. Thus, the outer layer of the embryo (the ectoderm or epiblast) forms in the adult (1) the outer skin or epidermis, (2) the nervous system, (3) much at least of the sense-organs: the inner layer of the embryo (the endoderm or hypoblast) forms at least an important part (the "mid-gut") of the food-canal, and the basis of outgrowths (lungs, liver, pancreas, etc.) which may arise therefrom, and

also the notochord of Vertebrates: the middle layer of the embryo (the mesoderm or mesoblast) forms all the rest, *e.g.*, skeleton, connective swathings, muscle, and (according to most authorities) the vascular system. But we shall return to this subject in the next chapter.

It is important to adopt some order of description. It is obviously prejudicial to the success of your work and to the health of your brains, to describe an animal in any order that occurs to you, to skip from food-canal to kidney, or from heart to reproductive organs. Therefore, in my descriptions I shall follow, almost consistently, this order of treatment:—mode of life, form, external appendages, skin, skeleton, muscle, nervous system, sense-organs, food-canal, body-cavity, vascular system, respiratory system, excretory system, reproductive organs, development.

III. Tissues.

Zoological anatomists, of whom Cuvier may be taken as type, analyse animals into their component organs, and discover the real resemblances or homologies between one animal and another. But as early as 1801, Bichât had published an *Anatomie Générale* in which he carried the analysis further, showing that the organs were composed of *tissues*, contractile, nervous, glandular, etc. In 1838–9, Schwann and Schleiden formulated the "cell theory," in which was stated the result of yet deeper analysis—that all organisms have a *cellular* structure and origin. The simplest animals (Protozoa) are almost always single cells or unit masses of living matter; as such all animals begin; and all, except the simplest, consist of hundreds of these cells united into more or less homogeneous companies (tissues) which may be compacted, as we have seen, into organs. If we think of the organism as a great city of cells, the tissues represent streets (like some of those in Leipzig) in each of which some one kind of industry predominates, while subsidiary activities are also retained.

The study of the structure of tissues and cells is sometimes called microscopic or minute anatomy, or is dignified by the special title of histology. Since Leydig gave a strong

foundation to comparative histology in his remarkable *Lehrbuch der Histologie des Menschen und der Thiere* (Frankfurt, 1857), the study has been prosecuted with great enthusiasm and success, and has been constantly stimulated by improvements in microscopic apparatus and technique.

We shall refer to interesting histological items in the course of our studies, meanwhile we shall consider very briefly the four great kinds of tissue :—Epithelial, Connective, Muscular, and Nervous.

(*a*) *Epithelial Tissue.*

In the development of many animals, the ovum divides and re-divides till a hollow ball of cells results. The cavity is bounded by a layer of similar cells, which often bear motile lashes or cilia on their outer ends. Such a layer of cells illustrates what is meant by epithelium, and the same simple kind of tissue composes all young embryos. Considered embryologically, epithelium is the most primitive kind of tissue.

Similarly, such an organism as *Volvox*, one of those which bridge the gulf between single-celled and many-celled animals, consists of a ball of cells not unlike the embryonic stage to which I have just referred. It is a hollow sphere of epithelium. So *Hydra* is a tubular animal, with two layers of cells, an external and an internal epithelium, in which complications have just begun to arise. Considered historically, epithelium is the most primitive kind of tissue.

In all epithelium which has not been much modified, the cells have two distinct poles. The outer pole is distinguished by cilia, or a sensitive process, or a passive cuticular rim, or pigment, etc., from the basal or internal one. We can readily understand this, if we think of *Volvox*, or of the hollow embryonic ball, where the outer parts of the cell obviously have a different environment from the internal ends. A great many different kinds of tissue retain traces of epithelial origin and of polar differentiations in their cells. But epithelial tissue has many different forms in the more complex animals. The external layer of the skin (epidermis), the internal lining of the food-canal and its outgrowths, the lining of the body-cavity, and the swathing of the organs moored therein (endothelium), are all epithelial. Epithelium may be single-layered or stratified ; its cells may be columnar, scale-like, or otherwise. The cells may be close together, or separated by intercellular spaces, and they are often connected by bridges of living matter. Nor are the functions of epithelium less diverse than its forms, for it may be ciliated (effecting locomotion, food-wafting, and respiration), or sensitive (and as such forming sense-organs), or glandular (liberating certain products or even the whole contents of its component cells), or pigmented (and thus associated with respiration, excretion, and protection), or covered externally with a sweated-off cuticle, susceptible of many modifications (especially of protective value).

(*b*) *Connective Tissue.*

I am afraid that this term is somewhat like the title "worms." It includes too many different kinds of things to mean much. It represents a sort of histological lumber-room.

The embryologists help us a little, for they have shown that all forms of connective tissue are derived from the mesoderm or middle layer of the embryo. As this mesoderm usually arises in the form of outgrowths from the gut, or from ("mesenchyme") cells liberated at an early stage from either (?) of the two other layers of the embryo (ectoderm or endoderm), we may say that connective tissue is primarily derived from epithelium. Sometimes, *e.g.*, in the lancelet (*Amphioxus*), this origin is very evident. Moreover, in the Sponges and Stinging-animals which have no strict mesoderm, there is usually a middle stratum ("mesoglœa"), of a gelatinous character in jellyfishes, with more abundant cells in Sponges. It must be included as a form of "connective tissue," and it is derived from the outer and inner layeis which enclose it.

The general function of "connective tissue" is to enswathe, to bind, and to support, but the forms assumed are very various.

(*a*) The cells may be close together, without any intercellular "mortar" or matrix. They may contain large vacuoles, and thus produce the appearance of a network, or they may be crammed with fat or with pigment.

(*b*) In other cases the cells of the connective tissue lie in a matrix, which they exude, or into which they in part die away. Such cells are very often irregular in outline, and give off in most cases fine processes, which traverse the matrix as a network. The fibrous tissue of tendons and the different kinds of gristle or cartilage, are good illustrations of connective tissue with much matrix. Cartilage is sometimes hardened by the deposition of lime salts in its substance, and then has a slight resemblance to another kind of "connective tissue"—bone. But bone, which is restricted to Vertebrate animals, is quite different from the cartilage which it often succeeds and replaces. It is made by strands or layers of special bone-forming cells (osteoblasts), which may rest on a cartilage foundation, or may be quite independent. These osteoblasts form the bone matrix, and some of them are involved in it, and become the permanent bone-cells. These have numerous radiating branches, and are arranged in layers, usually around a cavity or a blood-vessel. There are no blood-vessels in cartilage). The matrix becomes very rich in lime salts (especially phosphate); and the cartilage foundation, if there was one, is quite destroyed by the new formation. Here we may also note two important fluid tissues, the floating corpuscles or cells of the blood, and those of the body-cavity or "perivisceral" fluid, which is often abundant and important in backboneless animals.

(*c*) *Muscular Tissue.*

Origin.—The single-celled *Amœba* moves by flowing out on one side and drawing in its substance on another. It is diffusely contractile, and it has also sensitive, digestive, and other functions.

In *Hydra* and some other Cœlenterates, the bases of the epithelial cells which form the outer layer and line the internal cavity, are prolonged into contractile roots. By the activity of these muscular roots the *Hydra* elongates and contracts its body. Here then we have cells of which a special part discharges a contractile or muscular function, while the other parts of the cells retain other powers. (The external contractile cells in *Hydra* are often called "neuro-muscular," as if they combined nervous and muscular functions. It is possible that they do, but the existence of special nerve-cells does not favour the idea in this case at least.)

In other Cœlenterates, the muscular cells are still directly connected with the epithelium, but become more and more exclusively devoted to the function of contraction. In all other animals the muscular tissue is derived from the mesoderm, which, as we have already mentioned, is not distinctly present in Cœlenterates. In the majority the muscle-cells arise on the walls of the body-cavity, and their origin may often at least be justly described as epithelial. But in other cases the muscles are started by those wandering "mesenchyme" cells, to which we have already referred.

So, as regards origin, muscular tissue may be classified as follows :—

1. In Cœlenterates, where there is no definite "mesoderm," the muscle-elements arise from the ectodermic and endodermic epithelium, of which they often form a direct part. In the passive Sponges, the contractile elements are few and unimportant.
2. In other animals the muscle-elements arise from the middle layer, but O. and R. Hertwig distinguish between those which have an "epithelial" and those which have a "mesenchymatous" origin.

Structure.—A distinction is usually drawn between striped and un striped muscle-fibres, but, according to the Hertwigs, this distinction is of little morphological value.

Smooth or unstriped muscle-fibres are elongated contractile cells, externally homogeneous in appearance. They are especially abundant in sluggish animals, *e.g.*, Molluscs, and occur in the walls of the gut, bladder, and blood-vessels of Vertebrates, where they are somewhat quaintly called "involuntary." They are less perfectly differentiated than striped muscle-fibres, and usually contract more slowly.

A striped muscle-fibre is a cell, the greater part of which is modified into a set of parallel longitudinal fibrils, with alternating "clear and dark" transverse stripes. A residue of unmodified cell-substance, with a nucleus or with many, is often to be observed on the side of the fibre, and a slight sheath or sarcolemma forms the "cell-wall." Many muscle-fibres closely combined, and wrapped in a sheath of connective tissue, form a muscle, which, as every one knows, can contract with extreme rapidity when stimulated by a nervous impulse.

The contraction involves a visible change of form, associated with a chemical "explosion" in the cell-substance with the production of heat and waste-products, and with subtle changes of electric potential. One of the greatest marvels of animal life, is the strength and sustained power of muscles.

The minute structure of muscle has been studied with extraordinary enthusiasm for many years, but the result is not quite certain. According to many, there is within the muscle-fibre, as within many another cell, an intricate network with a more fluid stuff in its meshes. If this be true, it is likely enough that the strands of the network are the most directly important elements in contraction.

But most attention has been bestowed on the transverse markings, in regard to which there are many theories. I believe in the simplest, that of Dr. Berry Haycraft according to whose results the markings are optical effects due to the shape of the fibre. He maintains that the fibre is made up of many uniform ampullated or beaded fibrils. The "stripes" do not mark the position of alternating layers of different structure, they mark the shape of the fibre. Dr. Haycraft has recently found a conclusive corroboration of his reasonable theory, in the fact that muscle-fibres pressed upon a collodion film leave a stamp upon its surface, on which the cross-striping can be clearly seen and photographed.

(*d*) *Nervous Tissue.*

Origin.—Starting again with the *Amœba*, we recognise that it is sensitive, and that a stimulus can pass from one part of the cell to another.

In some Cœlenterates it is possible that some of the external cells combine contractile, nervous, and even other functions. Under this impression many call them "neuro-muscular."

But in *Hydra*, there are special nervous or sensitive cells, whose basal prolongations are connected with the contractile roots already described. Here there is a neuro-muscular apparatus of the simplest kind. The nerve-cells seem to receive impressions from without, and transmit them as stimuli to the contractile elements.

In sea-anemones (*Actinia*), and some other Cœlenterates, there is an interesting complication, withal very simple. There are superficial sensory cells, connected with subjacent nerve- or ganglion-cells, from which fibres pass to the contractile elements.

In higher animals the sensory cells are integrated into sense-organs, the ganglionic cells into ganglia, while the delicate fibres which form the connections between sensory cells and ganglionic cells, and between the latter and muscles, are represented by well-developed nerves.

Sensitive cells	analogous to	sense-organs of higher animals.
Basal prolongations	,,	sensory or afferent nerve-fibres.
Ganglion-cells	,,	brain or ganglia.
Fibrous prolongations	,,	motor or efferent nerve-fibres.
Muscular cells	,,	muscles.

So far as we know, nervous tissue always arises from the outer or ectodermic layer of the embryo, as we would expect from the fact that it is the layer which, in the course of history, has been most directly subjected to external influences. How nervous structures precisely arise,

and how they gradually become less superficial, we shall see in our systematic studies.

Structure.—Let us consider first the ganglionic cells which receive stimuli and shunt them, which regulate the whole life of the organism, and are the physical conditions of "spontaneous" activity and intelligence. The simplest are prolonged at one pole into an outgrowth which branches into an afferent and efferent nerve-fibre. Most, however, give off outgrowths from two poles or on all sides. Internally they exhibit a kernel or nucleus, and they consist in great part of a network or coil of fine fibrils. Within ganglia the ganglionic cells usually lie embedded in a fibrous cellular substance called neuroglia, which most histologists regard as an ensheathing and supporting material.

In all but a few of the simplest multicellular animals, the nerve-fibres are surrounded by a sheath called the neurilemma, which is said to be formed by adjacent connective tissue. Several nerve-fibres may combine to form a nerve, but each still remains ensheathed in its neurilemma. In vertebrate animals, each nerve-fibre usually consists of an internal "axis cylinder," the important part, and an external unessential medullary sheath whose texture suggests fat. But even in the higher Vertebrates, "non-medullated" or simply-contoured nerve-fibres are found in the sympathetic and olfactory nerves, and this simpler type alone occurs in hagfish, lamprey, and lancelet, as well as in all the Invertebrates with distinct nerves. Furthermore, it should be noted that nerves are usually surrounded by an enveloping nucleated layer called Schwann's sheath, or else by neuroglia.

Careful preparation of a nerve-fibre shows that it consists of numerous fibrils like those seen within a ganglion-cell. These are usually regarded as the essential elements in conducting impressions, but some maintain, whether rightly or wrongly I am not able to judge, that the essential part is the less compact, sometimes well-nigh fluid stuff between the fibrils, or that the fibrils are but the walls of tubes within which the essentially nervous stuff lies. As in other cases, the microscopic morphologists discover intricacies in regard to the import of which physiological conclusions are hardly possible.

But you may reasonably ask what these nerve-fibres are. I do not think that any one can at present give a decisive answer. According to most authorities, they are extensive prolongations of the ganglion-cells, and there is no doubt that the nerves of Vertebrates grow from the central system outwards. But to others it seems plausible that the neuroglia or other ensheathing elements contribute to the extension of the nerve-fibres, or rather that special cells make both sheath and fibre. It is possible that both theories are right.

IV. Cells.

In discussing tissues, it was necessary to refer to the component cells. Now we shall consider the chief characteristics of these elements.

A cell is a unit mass of living matter. Most of the simplest animals and plants (Protozoa and Protophyta) are single cells; eggs and male elements are single cells; but in the multicellular organisms the components are closely combined into tissues and organs.

Most cells are too small to be distinguished except through lenses; *Amœba*, *Paramœcium*, and many Protozoa are visible to our unaided eyes; the chalk-forming Foraminifera are single cells, whose shells are sometimes as large as pin-heads, and some of the extinct kinds were as big as half-crowns; the bast-cells of plants may extend for several inches; the largest animal cells are eggs distended with yolk.

History.—The word "cell" was first used in histological description by Hooke (1665), and Grew (1671–5), but not in a very accurate or definite way. Malpighi (1675) also described minute "utricles," some of which we should call cells.

Leeuwenhoek (*Phil. Trans.* 1674) seems to have been the first to describe single-celled organisms. In the eighteenth century the analysis continued; thus Rösel von Rosenhof described the "Proteus animalcule" or *Amœba* in 1755, and Fontana, in 1784, discovered the kernel or nucleus of the cell.

But the fact that Bichât, in his *Anatomie Générale* (1801), speaks of tissues only, shows that the import of cells was not realised at the beginning of this century.

In 1835, Robert Brown showed that a nucleus was normally present in all vegetable cells, and in the same year Johannes Müller definitely compared the cells of plants with those of the notochord in animals.

The cellular structure and origin of organisms began to be vaguely recognised by many. At length, in 1838-9, Schwann and Schleiden showed that all but the simplest plants and animals are built up of cells, and develop from cells, thus establishing the famous "cell theory":—"There is one universal principle of development for the elementary part of organisms however different, and this principle is the formation of cells."*

* Those interested in history should read the scholarly history of cell-lore by Sir William Turner, "The Cell Theory, Past and Present," Inaug. Address to Scottish Microscopical Society (Edin. 1890, also in *Nature*, 1890). See also Professor M'Kendrick *On the Modern Cell Theory* (Proc. Phil. Soc., Glasgow, 1888), also his text-book of Physiology. The articles Morphology and Protoplasm in the *Encyc. Brit.*, and the article Cell in the new edition of *Chambers's Encyc.*, should be consulted.

This doctrine was corroborated in many ways. Numerous investigators, Prévost and Dumas (1824), Martin Barry (1838–41), Reichert (1840), Henle (1841), Kölliker (1843–6), and Remak (1841–52), showed how the cells of the embryo arise from the division of the fertilised egg-cell.

Moreover, Goodsir in 1845, Virchow in 1858, proved that in all cases, pathological as well as normal, cells arise from pre-existing cells, that *omnis cellula e cellula* is a general fact of histology.

There was a strong tendency, however, to attach too much importance to the cell-wall, and too little to the contained cell-substance. The all-important protoplasm was not adequately appreciated.

In 1835, Dujardin described the "sarcode" of Protozoa, and other animal cells; in 1839, Purkinje compared the substance of the animal embryo with the "cambium" of plant-cells; in 1846, Von Mohl emphasised the importance of the "protoplasm" in vegetable cells; Ecker (1849) compared the contractile substance of muscles with the living matter of amœbæ; Donders also referred the contractility from the wall to the contents; Cohn suspected that the "sarcode" of animals and the "protoplasm" of plants must be "in the highest degree analogous substances;" and finally, Max Schultze (1861), accepted the growing belief that plants and animals were made of very similar living matter, and defined the cell as a unit mass of nucleated protoplasm. Since then biologists have concentrated their attention on the living matter which constitutes and gives form to the cell.

Forms of Cells.—The typical and primitive form of cell is a sphere,—a shape naturally assumed by a complex coherent substance situated in a medium different from itself. Most egg-cells and many Protozoa retain this primitive form, but the internal and external conditions of life (such as nutrition and pressures), often evolve other shapes,—oval, rectangular, flattened, thread-like. A cell has often two distinct poles, as we noticed in connection with epithelium, but some, like amœbæ and colourless blood-cells, are continually changeful, while others give off radiating processes on all sides.

Structure of Cells.—Cells consist (*a*) of the living substance or protoplasm, along with which we may include nutritive material in process of being incorporated, waste-products which result from the vital activity, and by-products formed in the course of the cell's life; (*b*) of a specialised kernel or nucleus, with a complex structure, and important but hardly definable functions in the life of the cell; (*c*) of a cell-wall or marginal sheath, which occurs in very varied form or may be entirely absent.

(*a*) *The Cell-Substance.*—When a simple cell is examined

DIAGRAM II.

THE CELL.

I. The figure marked Cell I. shows the cell-substance (*c.s.*) with granules and network, and the nucleus (*n.*)) with a coil of chromatin threads. (After Carnoy.)

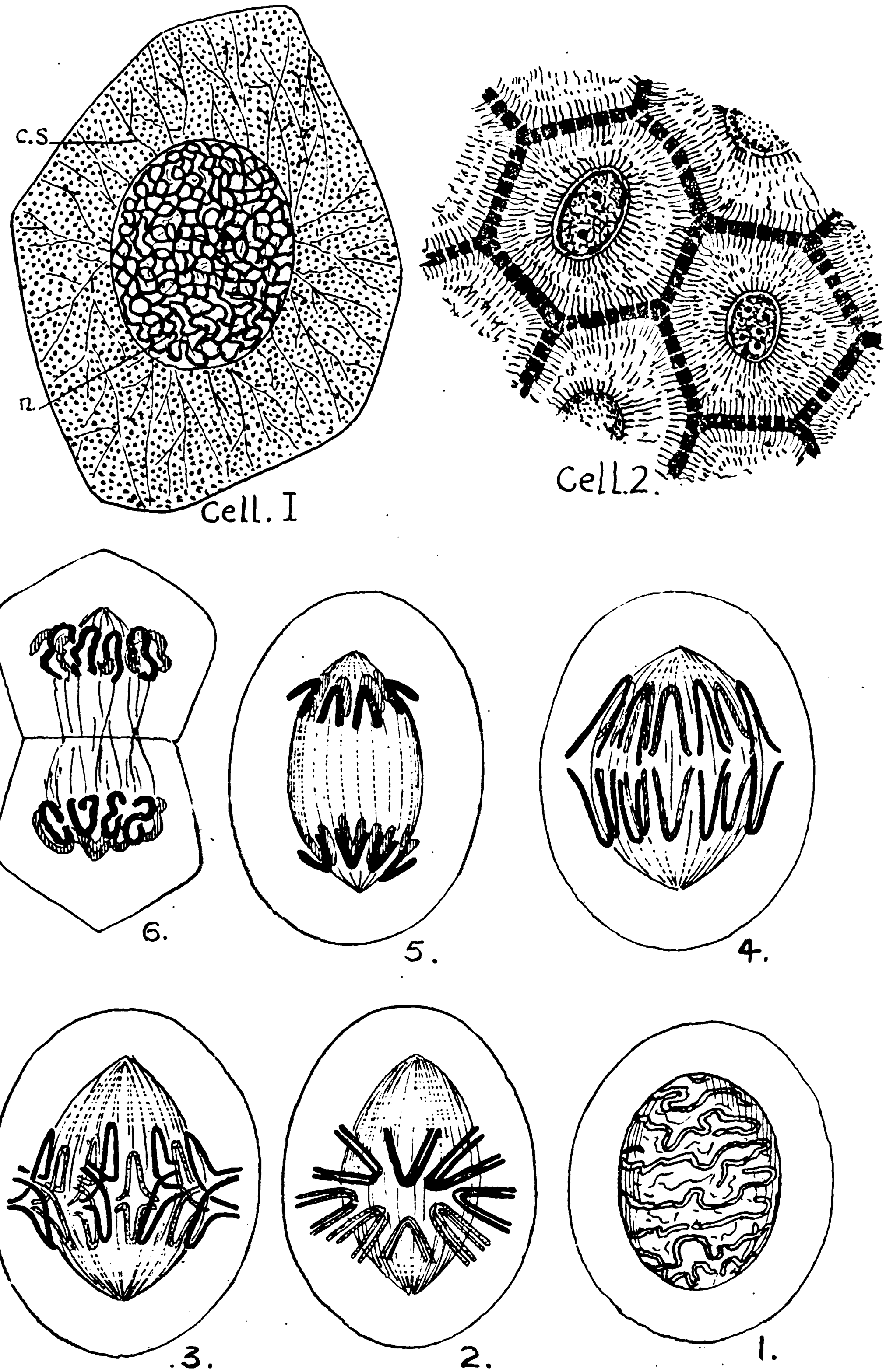
II. The figure marked Cell II. shows several adjacent cells with inter-cellular bridges of protoplasm between their cell-walls. (After Pfitzner.)

The lower half of the diagram shows the process of Karyokinesis. (From Hatschek, after Flemming.)

1. Shows the nucleus with a coil of chromatin threads (*b* in text, pp. 43-44).
2. Shows an aster at the equator of the nucleus (*c* in text).
3. Shows the longitudinal division of the chromatin loops (*d* in text).
4. Shows the diaster in which the halved chromatin loops are receding towards the poles (*e* in text).
5. Shows the polar position of the chromatin elements, and achromatin threads between them (*e* in text).
6. Shows the division of the cell, and the beginning of the process in which the daughter-nuclei are reconstituted (*f* in text).

Diagram II.

The Cell.



in its living state, it often appears approximately homogeneous. Its substance is usually slightly fluid, but it may be firm and compact in passive cells. It is usually translucent, but there are often obscuring granules of different kinds. In many cases, its appearance suggests a fine emulsion; indeed Bütschli has succeeded in making marvellous imitations of cells out of ingeniously contrived emulsions.

In thinking of the cell-substance, we must distinguish clearly between the genuinely living material or protoplasm, of whose nature we know almost nothing, and associated substances, such as starch, fat, or pigment, whose chemical composition can be ascertained. The associated substances which often crowd the protoplasm, are due to the chemical ascent of food-material towards protoplasm, or to the chemical disruption which protoplasm undergoes or produces as it lives.

When a small portion of an animal is "fixed" or hardened by some reagent like osmic, chromic, or picric acid, dehydrated by being soaked in various strengths of alcohol, stained with carmine or some other dye, dehydrated again in alcohol, soaked for hours in melted paraffin, cut in thin sections with a razor or microtome, cleared from the paraffin by immersion in turpentine, mounted in Canada balsam or the like, and examined under the high power microscope, details of cell structure can be seen which are rarely recognisable in the fresh unprepared cells. The cell-substance is far from being homogeneous; it seems to consist of a fine network with a more fluid material in the meshes. In other cases, the structure is more like that of an emulsion, with innumerable minute vacuoles. Within the cell-substance of reproductive cells and some others, several recent investigators have described a "central corpuscle," quite apart from the nucleus. It may be a "centre of force" within the protoplasm.

Many very valuable results in regard to the minute structure of cells have been reached by histologists, but there is sometimes a tendency to push the structural analysis beyond the limit of physiological interest; nor is it always remembered that the real structure of the cell may be considerably affected in the course of that complex technique, of which I have just given one of the simplest illustrations.

(*b*) *The Nucleus.*—Almost every cell contains a nucleus or

several. It used to be said that those very simple animals which Hæckel called Monera had no nuclei, but in several they have been recently discovered. In other cases, *e.g.*, some Infusorians, the nuclear material seems to be diffused in the cell-substance. The red blood-cells of Mammals seem to be distinctly nucleated in their early stages, but there is no trace of a nucleus in those which are full grown. But we may safely say that cells without nuclei are *very* rare, though in some cells the nuclei are certainly less differentiated than in others.

The nucleus is a very important part of the cell, but it is not possible to define precisely what its importance is. In fertilisation, the most essential process is the union of the nucleus of the spermatozoon or male-cell with the nucleus of the ovum or female cell. In cell-division, the nucleus certainly plays an essential part. Cells bereft of their nuclei die, or for a time live a crippled life. On the other hand, there is no doubt that the substance of the cell also influences the nucleus.

The nucleus often lies within a little nest in the midst of the cell-substance, but it may shift its position within the cell. It has a definite margin, but this may be lost, *e.g.*, before cell-division begins. Internally, it is anything but homogeneous; at any rate, homogeneous nuclei are rare. As in the general cell-substance, so here, the histologists have discovered a network of fine strongly stainable (chromatin) strands, with less stainable (achromatin) substance in the meshes. But in other cells, or at another time in the same cell, the nucleus is seen to contain a coiled (chromatin) thread, or a number of chromatin loops. Many nuclei also contain one or more little round bodies or nucleoli, apparently of less importance. Within the nucleolus an "endonucleolus" has been discovered. Though the nuclei of different cells are often different in small details, there is a marvellous unity, both of structure and activity, throughout the world of cells.

(*c*) *The Cell-Wall.*—To the earlier histologists, who often spoke of cells as little bags or boxes, the wall seemed of much moment. It is, however, the least important part of the cell. In plant cells there is usually a very distinct wall consisting of cellulose. This has the same chemical composition

as starch, and is a product, not a part, of the protoplasm, though some protoplasm may be intimately associated with it as long as its growth continues. In animal cells there is rarely a very distinct wall chemically distinguishable from the living matter itself. But the margin is often different from the interior, and a slight wall may be formed by a superficial compacting of the threads of the cell-network, or by a physical alteration of the cell-substance, comparable to the formation of a skin on cooling porridge. In other cases, especially in cells which are not very active, such as ova and encysted Protozoa, a more definite sheath is formed around the cell-substance. Thirdly, animal cells may form a superficial "cuticle," sometimes of known chemical composition, witness the chitin formed by the outer-layer cells in Insects, Crustaceans, and other Arthropods.

In animals, as well as in plants, adjacent cells are some times linked by inter-cellular bridges of living matter.

Cell-Division.—Though the division of cells, by which all growth is affected, is a subject with which the physiologist is as much concerned as the morphologist, it will be convenient to discuss it here. The following facts are most important.

(1) We know that there is a striking unity in all cases, and that the nucleus plays an essential part in the process. It passes through a series of changes known as karyokinesis, and these are much the same everywhere. But it also seems true that a simpler mode of division (sometimes called "direct") occurs in some Protozoa and in some cells of higher animals.

(2) The eventful changes of the dividing nucleus are in general terms as follows:—

(*a*) The *resting stage* of the nucleus shows a network of filaments (chromatin threads).

(*b*) *Coil Stage.*—As division begins, the membrane separating the nucleus from the cell-substance disappears, and the chromatin threads are seen as an irregular coil like a small ball of twine.

(*c*) *Aster-stage.*—The threads of the coil break into looped pieces which are disposed in a star, the free ends of the U-shaped loops being directed outwards. Meanwhile, from two "central corpuscles,"

situated in the cell-substance at each pole of the cell, fine "achromatin" threads run into connection with the chromatin loops.

(*d*) *Division and separation of the loops.*—Each of the loops which make up the star divides *longitudinally* into two, and each half separates from its neighbour. They are apparently drawn to opposite poles of the cell.

(*e*) *Diaster.*—The single star is thus drawn out into two daughter stars which separate further and further from one another towards the opposite poles of the cells.

(*f*) Each daughter star is reconstituted into a coil in each daughter cell, for the cell-substance has also been halved meanwhile. The halves will separate in the case of Protozoa, but in most other cases, as in growing embryos, they will of course remain adjacent with a slight wall between them.

(*g*) Each daughter nucleus then passes into the normal resting phase.

Flemming gives the following summary of karyokinesis :—

MOTHER-NUCLEUS (progressive changes). ↓	DAUGHTER-NUCLEUS (regressive changes). ↑
a Resting stage.	Resting stage. *g*
b Coil.	Coil. *f*
c Aster.	Aster (Diaster). *e*

⟶ *d* Division of Aster and its loops (metakinesis). ⟶

(3) It is not in the least likely that we shall ever be able to give even an approximate account of the "mechanism" of cell-division. Rapidly progressive research has disclosed many mysteries, but it does not explain them. The nucleus is resolved into a chromatin framework and an achromatin matrix, but the chromatin threads behave like little individuals. The longitudinal division of each loop shows, as Roux points out, how rigidly exact is the partition of substance and implied qualities. The "central corpuscles," recently discovered, act like centres of force, and the indescribably fine threads, which pass from these to the chromatin loops, have been credited with contractile powers. The certain fact is that the whole process is vital, and therefore

inexplicable in terms of matter and motion, so long at least as we do not know the secret of protoplasm.

(4) On the other hand, Leuckart and Spencer have given a general rationale of cell-division. Why do not cells grow much larger, why do they almost always divide at a definite limit of growth? Their answer is as follows. Suppose a young cell has doubled its original mass, that means that there is twice as much living matter to be kept alive. But the living matter is fed, aerated, purified through its surface, which, in growing spherical cells for instance, only increases as the square of the radius, while the mass increases as the cube. The surface growth always lags behind the increase of mass. Therefore, when the cell has, let us say, quadrupled its original mass, but by no means quadrupled its surface, difficulties set in, waste begins to gain on repair, anabolism loses some of its ascendancy over katabolism. At the limit of growth, then, the cell divides, halving its mass and gaining new surface. Of course surface may be increased by outflowing processes, just as it is by the lobes of many leaves, and division may occur before the limit of growth is reached, but as a general rationale, applicable to organs and bodies as well as to cells, the suggestion of Leuckart and Spencer is very helpful.

Protoplasm.—I have spoken of the structure of living matter or protoplasm in describing cells. I insert this heading simply to emphasise anew that the morphological as well as the physiological analysis passes from the organism as a whole to its organs, thence to the tissues, thence to the cells, and finally to the protoplasm itself.

CHAPTER IV.

THE REPRODUCTION AND LIFE-HISTORY OF ANIMALS.

I. Reproduction.

In the higher animals the beginnings of individual life are hidden, within the womb in mammals, within the egg-shell in birds. It is natural, therefore, that early preoccupation with those higher forms should have hindered the recognition of what seems to us an evident fact, that almost every organism, whether plant or animal, arises from an egg-cell or ovum which has been fertilised by a male-cell or spermatozoon. The exceptions to this fact are those organisms which multiply by buds or detached overgrowths, and those which arise from an egg-cell which requires no fertilisation. Thus *Hydra* may form a separable bud, much as a rose-bush sends out a sucker; thus drone-bees "have a mother but no father," for they arise from parthenogenetic eggs which are not fertilised. Apart from these and similar cases, the "ovum theory," which Agassiz called "the greatest discovery in the natural sciences in modern times," is true,—that each organism begins from the division of a fertilised egg-cell. We can easily see this simple beginning in the frog-spawn from the ditch, in the eggs of salmon, in those of the pond-snail (*Lymnæus*), and in hosts of other cases.

History.—Perhaps we can realise this discovery better if we consider its history. For a long time, on into the present century, what was called the doctrine of *preformation* prevailed. According to this theory, development was merely an unfolding ("evolution") of a preformed miniature which lay within the germ. The "ovists" found this miniature model of the future organism in the egg; the "animalculists" found and even figured it within the spermatozoon. "There is no becoming," said Haller, "no part of the body is made from another, all are created at once." But this was not all. The germ was more than

a marvellous bud-like miniature of the adult, it included the next generation, and the next, and the next, and all future generations. Germ lay within germ, preformed in transparency, and in successively smaller miniature, after the fashion of an infinite juggler's box. We laugh at this, but we need not laugh too much, for the preformationists, though entirely wrong and crude in their facts, were right in two of their ideas, —that the germ, in reality, does contain the possibility of a future organism, and that it has relations, not only to the animal into which it develops, but also to generations following.

In the middle of the seventeenth century, however, Harvey had reached conclusions which might have saved much blundering. Studying the development of the chick,—as Greek naturalists had tried to do well-nigh two thousand years before, as we are doing still in our embryological laboratories,—Harvey maintained that every animal was produced from an ovum (*ovum esse primordium commune omnibus animalibus*), and that organs arose by new formation (*epigenesis*), not by the mere expansion or "evolution" of some invisible preformation.

But the great champion of epigenesis was Caspar Friedrich Wolff, who, in his doctorial dissertation of 1759, traced the chick back to a layer of organised particles (the familiar *cells* of to-day), in which there was no likeness of the future embryo, far less adult.

Wolff was long in finding successors, but in 1824 Prévost and Dumas described the division of the ovum into masses (segmentation); in 1827 Von Baer discovered the mammalian ovum; while Wagner, Von Siebold, and others elucidated the real nature of the spermatozoa.

A great step was made in 1838-9, when Schwann and Schleiden formulated the "cell theory," according to which every organism is made up of cells, and starts from a cell. From this date modern embryology began, and has of late years made advances greater perhaps than those of any other department of zoology.

Sexual Reproduction.—There is apt to be a lack of clearness in regard to sexual reproduction, because the process which we describe by that phrase is a complex result of evolution. It involves two distinct facts :—(*a*) the liberation of special germ-cells from which new individuals arise; (*b*) the occurrence of two different kinds of germ-cells—ova and spermatozoa, which are fertile only when they unite (fertilisation). Furthermore, these dimorphic reproductive cells are produced by two different kinds of individuals (females and males), or from different organs of one individual, or at different times within the same organ (hermaphroditism).

It is quite evident that organisms might have gone on multiplying asexually, by detaching overgrown portions of themselves which had sufficient vitality to develop into complete forms. But a more economical method is the liberation of special germ-cells, in which the qualities of the

organism are inherent. This is the primary characteristic of sexual, as opposed to asexual multiplication.

It is also an evident possibility that the organisms of a species might have remained approximately like one another in constitution, and at all times very nearly the same. Then there would have been no difference of sex, no males and females, nor even hermaphrodites with alternating male and female periods. It is quite possible to think of a race of animals in which all the individuals were approximately the same, and liberated similar germ-cells which grew up right away. This would be sexual as distinguished from asexual multiplication, but it would not exhibit that other characteristic of sexual reproduction,—the existence of dimorphic germ-cells, which come to nothing if they do not combine, and of different kinds of individuals (male and female), or of different sexual periods in the life of one (hermaphrodite) individual.

The Liberation of Special Germ-Cells.—I believe that one must think of this as an economical improvement on the method of starting a new life by asexual overgrowth or by the liberation of buds. Asexual reproduction, as Spencer and Hæckel have shown, is a mode of overgrowth in which the bud, or whatever it is, may become discontinuous from the parent. The buds of a sponge, of a coral, of a sea-mat (Polyzoon), or of many Tunicates, remain attached to the parent. If there be a keen struggle for subsistence, this may be very disadvantageous; but in some cases, doubtless, the colonial life which results is a source of strength. In the case of *Hydra*, however, the buds are set adrift; the same is true of not a few worms. This liberation of buds takes us nearer the sexual process of liberating special germ-cells. But unless the organism is in very favourable nutritive conditions, in which overgrowth is natural, the liberation of buds is evidently an expensive way of continuing the life of a species. Not only so, but we can hardly think of budding even as a possibility in very complex organisms like snails or birds, in which there is much division of labour. Moreover, the peculiarity of a true germ-cell is, that it is unspecialised, continuous in quality with the original germ-cell from which the parent arose, and not very liable to be tainted by any mishaps which may

befall the "body" which bears it. In short, the asexual method of liberating buds has been replaced in most animals by the liberation of special germ-cells, by the more economical and advantageous process of sexual reproduction.

SUMMARY OF MODES OF REPRODUCTION.

A. *In single-celled Animals* (Protozoa).

(1) The almost mechanical rupture of an amœboid cell, which has become too large for physiological equilibrium (*e.g.*, *Schizogenes*).
(2) The discharge of numerous superficial buds at once (*e.g.*, *Arcella* and *Pelomyxa*).
(3) The formation of one bud at a time (very common).
(4) The ordinary division into two daughter cells at the limit of growth.
(5) Successive divisions within limited time and within limited space (a cyst). This results in what is called spore-formation, "free-cell formation," "endogenous multiplication" (*e.g.*, in Gregarines).

B. *In many-celled Animals* (Metazoa).

(*Asexual.*)

(*a*) The separation of a clump of body-cells, *e.g.*, from the surface of some Sponges (A crude form of budding.)
(*b*) The formation of definite buds which may or may not be liberated; and other forms of asexual multiplication.

(*Sexual.*)

(*a*) The liberation of cells from a simple Metazoon in which there is so little division of labour that the distinction between body cells and reproductive cells is not marked. (Hypothetical.)
(*b*) The liberation of special reproductive or germ cells, which have not taken part in the formation of the body, and which retain unaltered the inherent qualities of the original germ-cell from which the parent arose. (The ordinary process.)

In the animal series, the sexual method of liberating special germ-cells has predominated, as every one is aware, over the asexual method of forming buds. Moreover, the sexual method has been accentuated in most animals by the evolution of two sexes, which produce different kinds of germ-cells—ova and spermatozoa.

The Evolution of Sex.—Our problem now is not that of accounting for the fact that most animals liberate special reproductive cells, but for the two facts, (*a*) that most animals are either males or females, the former liberating actively motile male-elements or spermatozoa, while the latter form and usually liberate more passive egg-cells or ova; and (*b*) that these two different kinds of reproductive cells usually come to nothing unless they combine.

The problem is partly solved by a clear statement of the facts. Begin with those interesting organisms which are on the border-line between Protozoa and Metazoa, the colonial Infusorians of which *Volvox* is a type. As adults they are balls of cells, and the component units are connected by protoplasmic bridges. From such a ball of cells reproductive units are sometimes set adrift, and these divide to form other individuals without more ado. In other conditions, however, when nutrition is checked, a less direct mode of reproduction occurs. Some of the cells grow at the expense of their neighbours, and become large well-fed elements, or ova; others, less successful in the exploitation of their neighbours, divide into many little units. The large cells are fertilised by the small. Here we see the formation of dimorphic reproductive cells in different parts of the same organism. But we may also find *Volvox* balls in which only ova are being made, and others in which only small motile reproductive cells are being made. The former seem to be more vegetative and nutritive than the latter; we call them female and male organisms respectively; we are at the foundation of the differences between the two sexes.

All through the animal series, from active Infusorians and passive Gregarines, to feverish Birds and more sluggish Reptiles, we read antitheses between activity and passivity, between lavish expenditure of energy and a habit of storing, between relative disruptive (*katabolic*) predominance, and relative constructive (*anabolic*) predominance in the proto-

plasmic life of the creature. We believe that the contrast between the sexes gives almost universal expression to this fundamental alternative of variation.

This theory may be confirmed in many ways, *e.g.*, by contrasting the characteristic products of female life,—passive ova, with the characteristic products of male life,—active spermatozoa; or by comparing the complex conditions (such as abundant food, favourable temperature) which tend to produce female offspring with the opposite conditions which tend to produce males; or by contrasting the secondary sexual characters of males (*e.g.*, bright colours, and smaller size), with the opposite characteristics of females.

Stages in the History of Fertilisation.

(*a*) *Formation of Plasmodia*, the flowing together of numerous feeble cells, as seen in the life-history of those very simple Protozoa called Proteomyxa, *e.g.*, *Protomyxa*, and Mycetozoa, *e.g.*, flowers of tan (*Æthalium septicum*).

(*b*) *Multiple Conjugation*, in which more than two cells unite and fuse together, a process said to occur in some Gregarines, in the sun-animalcule (*Actinosphærium*), and in some simple Algæ.

(*c*) *Ordinary Conjugation*, in which two similar cells fuse together, observed in Gregarines, Rhizopods, and many Algæ. In ciliated Infusorians, the conjugation is a temporary union, during which nuclear elements are interchanged.

(*d*) *Dimorphic Conjugation*, in which two cells different from one another fuse into one, a process well illustrated in *Vorticella* and related Infusorians, where a little, active, free-swimming (we may say, male) cell unites with a fixed individual of normal size, which may fairly be called female.

(*e*) *Fertilisation*, in which spermatozoa liberated from a Metazoon unite intimately with ova liberated from another individual of the same species.

Divergent Modes of Sexual Reproduction.

(*a*) *Hermaphroditism* is the union of male and female

sexual functions in varying degrees within one organism. It may be demonstrable in early life only, and disappear as maleness or femaleness predominates in the adult. It may occur as a casualty or as a reversion; or it may be normal in the adult, *e.g.*, in some Sponges and Cœlenterates, in many "worms," *e.g.*, earthworm and leech, in barnacles and acorn-shells, in one species of oyster, in the snail, and in many other Bivalves and Gastropods, in Tunicates and in the hagfish. In most cases, though these animals are bisexual, they produce ova at one period and spermatozoa at another. It is, therefore, very rarely (in parasitic flat worms) that the ova of a hermaphrodite are fertilised by the spermatozoa of the same animal. There can be little doubt that the bisexual or hermaphrodite state, of periodic maleness and femaleness, is the primitive condition, and that the unisexual condition of permanent maleness or femaleness is a secondary differentiation. The cases which we have cited above, may be interpreted as due to persistence of the primitive condition, or as reversions to it.

(*b*) *Parthenogenesis*, as we know it, is a degenerate form of sexual reproduction, in which ova produced by female organisms develop without being fertilised by male elements. In the hypothetical primitive Metazoa there perhaps was a constant parthenogenesis, in which all the germ-cells were alike capable of developing into organisms without any mutual assistance. As we know it, however, parthenogenesis is a degenerate form of the normal sexual process. It is well illustrated by Rotifers, in which fertilisation is not known to occur, while in some genera males have never been found; by many small Crustaceans whose males are absent for a season; by aphides, from among which males may be absent for the summer (or in artificial conditions for several years) without affecting the rapid succession of female generations; by the production of drones in the bee-hive,—for the eggs which give rise to these (male) forms are unfertilised. With the exception of this last case and one other, in neither of which parthenogenesis can be said to have established itself thoroughly, all the parthenogenetic ova that have been carefully examined form only one polar body (see p. 56). There is reason for supposing that such ova are less exclusively female than those

usually produced, that they have some of the qualities of male-cells. We may think of them as reversions to the primitive type of germ-cell, such as was probably produced by Metazoa in which neither maleness nor femaleness was as yet differentiated.

(*c*) *Alternation of Generations.*—A fixed asexual hydroid or zoophyte (campanularian or tubularian) often buds off and liberates sexual medusoids or swimming-bells, whose fertilised ova develop into embryos which become fixed and grow into hydroids. This is the simplest illustration of alternation of generations.

The liver-fluke (*Distomum hepaticum*) of the sheep produces eggs which when fertilised grow into embryos. Within the latter, certain cells (which can hardly be called eggs) grow into numerous other larvæ of a different form. Within these the same process is repeated, and finally, the larvæ thus produced grow (in certain conditions) into sexual liver-flukes. In this case, reproduction by special cells like undifferentiated precocious ova, alternates with reproduction by ordinary fertilised egg-cells. So, too, the vegetative sexless "fern-plant" gives rise to special spore-cells, which develop into an inconspicuous bisexual "prothallus," from the fertilised egg-cell of which a "fern-plant" springs.

Various kinds of alternation are seen in the life-cycle of the fresh-water sponge, in the stages of the jellyfish *Aurelia*, in the history of some "worms" and Tunicates. They illustrate a rhythm between asexual and sexual multiplication, between parthenogenetic and normally sexual reproduction, between vegetative and animal life, between a relatively "anabolic" and a relatively "katabolic" preponderance.

II. EMBRYOLOGY.

The Egg-cell or Ovum. — Almost every multicellular organism begins life as an egg-cell with which a male-cell or spermatozoon has entered into intimate union. The exceptional occurrence of asexual multiplication and parthenogenesis has been explained.

The most important characteristic of the reproductive cells,

whether male or female, is that they retain the essential qualities of the fertilised ovum from which the parent animal was developed.

The ovum has the usual characters of a cell: its substance is traversed by a fine protoplasmic network; its nucleus or germinal vesicle contains the usual chromatin elements; it has often a distinct sheath representing a cell-wall.

In Sponges, the ova are well-nourished cells in the middle stratum of the body; in Cœlenterates, they seem to arise in connection with either outer or inner layer (ectoderm or endoderm); in all other animals, they arise in connection with the middle layer or mesoderm, usually on an area of the epithelium lining the body-cavity. In lower animals they often arise somewhat diffusely; in higher animals their formation is restricted to distinct regions, and usually to definite organs—the ovaries.

The young ovum is often like an amœba, and that of *Hydra* retains this character. It grows at the expense of adjacent cells, or by absorbing material which is contributed by special yolk-glands or supplied by the vascular fluid of the body.

The yolk or nutritive capital may be small in amount, and distributed uniformly in the cell as in the ova of Mammals, of earthworm, starfish, and sponge; or it may be more abundant, sinking towards one pole as in the egg of the frog, or accumulated in the centre as in the eggs of Insects and Crustaceans; or it may be very copious, dwarfing the formative protoplasm, as in the eggs of Birds, Reptiles, and some Fishes.

Round the egg there are often sheaths or envelopes of various kinds, (*a*) made by the ovum itself, and then very delicate (*e.g.*, the vitelline membrane); (*b*) often formed by adjacent cells (*e.g.*, the follicular envelope); or (*c*) formed by special glands, or by glandular cells in the walls of the oviducts (*e.g.*, the "shells" of many eggs). The envelope is often firm, witness the chitinous coat round the eggs of many Insects. In these cases there is often a little aperture (micropyle) through which alone the spermatozoon can enter. The hard calcareous shells round the eggs of Birds and Tortoises, or the "horny" mermaid's purse enclosing the

egg of a skate or of another gristly fish, are of course formed after fertilisation. Egg-shells must be distinguished from the egg-capsules or cocoons, *e.g.*, of the earthworm, in which several eggs are wrapped up together.

The Male-Cell or Spermatozoon is a much smaller and usually a much more active cell than the ovum. In its minute size, locomotor energy, and persistent vitality, it resembles a flagellate monad, while the ovum is comparable to an amœba or to one of the more encysted Protozoa.

A spermatozoon has usually two distinct parts : the essential "head," consisting mainly of nucleus, and the mobile "tail" which is often fibrillated. A small median portion connects head and tail. The spermatozoa of Threadworms and Crustaceans are sluggish, and inclined to be amœboid.

It is not quite accurate to say that the spermatozoon is homologous with the ovum, Both are true cells, and they are complementary, but the spermatozoon has a longer history behind it. The homologue of the ovum is the mother-sperm-cell or spermatogonium. This segments as the ovum does, but the units into which it divides have little coherence. They go apart and become spermatozoa. There is a striking resemblance between the different ways in which a mother-cell divides and the various kinds of segmentation in ova. In most cases the spermatogonium divides into spermatocytes, which usually divide again into spermatides or young spermatozoa.

Maturation of the Ovum.—When the egg-cell attains its definite size or limit of growth, it bursts from the ovary or from its place of formation, and in favourable conditions meets either within or outside the body with a spermatozoon from another animal. Before this union between ovum and spermatozoon is effected, generally indeed before it has begun, the nucleus or germinal vesicle of the ovum moves to the periphery and divides twice. This division results in the formation and extrusion of two tiny cells or polar globules, the first containing half, the second necessarily a quarter of the nuclear material which composed the germinal vesicle. The remaining nucleus of the ovum is reduced to a quarter of its original mass, but the *number* of chromatin threads which it contains is the same throughout. It is noteworthy that the second division follows close on

the first without the intervention of the "resting stage," which usually succeeds a nuclear division. The extruded polar bodies come to nothing, though they may linger for a time in the precincts of the ovum, and may even divide. The extrusion of polar globules from mature ova seems to be almost universal among animals; but observations are lacking in regard to Birds and Reptiles. Moreover, Weismann and Ischikawa have shown that in all parthenogenetic ova which they have examined only one polar body is formed. Blochmann indeed finds that in the eggs which give rise to drone-bees, and in one other case of parthenogenesis, two polar bodies are formed as usual. But in neither of these two exceptional cases is the parthenogenesis habitual; thus many of the eggs which the queen-bee lays are fertilised, and give rise to queens and workers. So far the admitted facts about polar bodies, but their theoretical interpretation is much disputed.

(1) Minot, Balfour, and Van Beneden have suggested that the polar globules represent extrusions of male substance from the egg. The non-formation or retention of one polar body in parthenogenetic ova replaces the otherwise necessary sperm, and makes development possible.

(2) Bütschli, Giard, and others have considered the problem historically, and interpret the premature division of the ovum as a survival of an ancient habit. Just as the mother-sperm-cell divides into units, so the unfertilised ovum divides, though to a less extent. The polar bodies thus represent rudimentary or abortive germ-cells. It is difficult, however, to explain why the habit should so constantly persist.

(3) Weismann supposes that the two polar bodies are different from one another. The first goes off with a nuclear substance which was only of use when the egg was a-making; the second effects a quantitative reduction of the more essential nuclear stuff or germ-plasma, thus making room for the addition of a corresponding quantity by the fertilising spermatozoon. Parthenogenetic ova give off only the first kind of substance, and are thus able to divide and develop without the aid of a spermatozoon. But there is no evidence that the two polar bodies are different from one another; the fact that the second follows the first without the intervention of a resting stage, suggests the very reverse. Nor does it seem to me probable that the power of developing depends merely upon the presence of a definite quantity of "germ-plasma," retained in parthenogenetic ova, gained in other cases by the addition of a sperm nucleus, which furnishes the equivalent of that which has just been parted with in forming the second polar body.

(4) A combined theory is that the ovum divides like any other cell, or like its Protozoon ancestors (2), at the limit of growth; that the extrusion does in some way differentiate the ovum, perhaps by eliminating waste or male products (1); and that the reduction of the germinal

vesicle is somehow a necessary preparation for its union with the fertilising nucleus of the sperm.

In the differentiation of some male-cells, processes somewhat analogous to the formation of polar bodies have been observed.

Fertilisation.—In the seventeenth and eighteenth centuries, some naturalists, nicknamed "ovists," believed that the ovum was all-important, only needing the sperm's awakening touch to begin unfolding the miniature model which it contained. Others, nicknamed "animalculists," were equally confident that the sperm was essential, though it required to be fed by the ovum. Even after it was recognised that both kinds of reproductive elements were essential, many thought that their actual contact was unnecessary, that fertilisation might be effected by an *aura seminalis.* Though spermatozoa were distinctly seen by Hamm and Leeuwenhoek in 1677, their actual union with ova was not observed till 1843, when Dr. Martin Barry detected it in the rabbit.

Of the many facts which we now know about fertilisation, the following are the most important:—

(1.) Apart from the occurrence of parthenogenesis in a few of the lower animals, an ovum begins to divide only after a spermatozoon has united with it. After one spermatozoon has entered the ovum, the latter ceases to be receptive, and other spermatozoa are excluded. If, as rarely happens, several spermatozoa effect an entrance into the ovum, the result is pathological.

(2.) The union of spermatozoon and ovum is very intimate; the nucleus of the spermatozoon and the modified nucleus of the ovum move or are drawn to one another, combining in a very orderly way to form a single nucleus.

(3.) When this combined or segmentation nucleus starts the process of development by dividing, each of the two daughter nuclei which result consists partly of material derived from the sperm-nucleus, partly of material derived from the ovum-nucleus. In other words, the union is orderly as well as intimate, and the subsequent division is so exact, that the qualities so marvellously inherent in the sperm-nucleus (those of the male parent), and in the ovum-nucleus (those of the mother animal), are diffused throughout the body of the offspring, and persist in its reproductive cells.

As to the interpretation of these facts, Weismann maintains the importance of the quantitative addition which the sperm-nucleus makes to the diminished nucleus of the ovum. At the same time, he finds the immediate source of all the variations in animals in that mingling of two nuclear plasmas which occurs as we have noted, in fertilisation. Others believe that the mingling diminishes the risk of unfavourable idiosyncrasies being transmitted from parents to offspring. Others emphasise the idea that the sperm supplies a vital stimulus to the ovum.

Segmentation.—The different modes of division exhibited by fertilised egg-cells depend in great measure on the quantity and disposition of the passive and nutritive yolk-material, which is often called deutoplasm in contrast to the active and formative protoplasm. The pole of the ovum at which the formative protoplasm lies, and at which the spermatozoon enters, is often called the animal pole; the other, towards which the yolk tends to sink, is called the vegetative.

We shall now contrast the chief modes of segmentation, but it should be recognised that they are all connected by gradations.

A. Complete Division—Holoblastic Segmentation.

I. Eggs with little and diffuse yolk-material divide completely into approximately equal cells,

[or, Ova which are alecithal (*i.e.*, without yolk) undergo approximately equal holoblastic segmentation].

This is illustrated in most Sponges, most Cœlenterates, some "worms," most Echinoderms, some Molluscs, in all Tunicates and in *Amphioxus*, and also in most Mammals.

II. Eggs with a little yolk-material accumulated towards one pole, divide completely, but into unequal cells,

[or, Ova without very abundant deutoplasm, but with what they have lying towards one pole (telolecithal), undergo unequal holoblastic segmentation].

This is illustrated in some Sponges, some Cœlenterates (*e.g.*, Ctenophora), some "worms," many Molluscs, in the lamprey, in Ganoid Fishes, in Amphibians.

B. Partial Division—Meroblastic Segmentation.

III. Eggs with a large quantity of yolk, on which the formative protoplasm lies as a small disc at one pole, divide partially, and in discoidal fashion,

[or, Ova which are telolecithal, and have a large quantity of deutoplasm, undergo meroblastic and discoidal segmentation].

This is illustrated in all Cuttle-fishes, all Elasmobranch and Teleostean fishes, all Reptiles and Birds, and also in the Monotremes or lowest Mammals.

IV. Eggs with a considerable quantity of yolk, accumulated in a central core, and surrounded by the formative protoplasm, divide partially and superficially or peripherally,

[or, Ova which are centrolecithal undergo meroblastic and superficial segmentation].

This is illustrated by almost all Arthropods, and by them alone.

Summarising the above, we have :—

A. Complete Division.	I. Equal. II. Unequal.
B. Partial Division.	III. Discoidal. IV. Superficial.

Blastosphere and Morula.—The result of division is usually a ball of cells. But when the yolk is very abundant (III.) a disc of cells—a discoidal blastoderm— is formed at one pole of the mass of nutritive material which it gradually surrounds.

As the cells divide and re-divide, they often leave a spacious central cavity, and a hollow ball of cells—a blastosphere or blastula—results.

But if the so-called "segmentation cavity" be very small or absent, a solid ball of cells or morula, like the fruit of bramble or mulberry, results.

Gastrula.—The next great step in development is the establishment of the two primary germinal layers, the outer ectoderm and the inner endoderm, or the epiblast and the hypoblast.

One hemisphere of the hollow ball of cells may be apparently dimpled into the other, as we might dimple an indiarubber ball which had a hole in it. Thus out of a hollow ball of cells, a two-layered sac is formed—a gastrula formed by invagination or *embolé.* The mouth of the gastrula is called the blastopore, its cavity is the archenteron.

But where the ball of cells is practically a solid morula, the apparent in-dimpling cannot occur in the fashion described above. Yet in these cases the two-layered gastrula is still formed. The smaller, less yolk-laden cells, towards the animal pole, gradually grow round the larger yolk-containing cells, and a gastrula is formed by overgrowth or *epibolé.*

In the course of our studies, we shall have opportunity to discuss various forms of gastrulation, and as to some other processes by which two layers are established, such as that called *delamination.* These are so rare that I need not here take any account of them.

Mesoderm.—We are not yet able to make general statements of much value in regard to the origin of the middle germinal layer—the mesoderm or mesoblast. In Sponges and Cœlenterates there is really none, but a gelatinous stuff (*mesoglœa*) appears between ectoderm and endoderm, and into this there wander cells from these two layers. In the other Metazoa, the middle layer may arise from a few *primary mesoblasts* or cells which appear at an early stage between the ectoderm and endoderm (*e.g.*, in the earthworm's development); or from numerous "*mesenchyme*" immigrant cells, which are separated from the walls of the blastosphere or of gastrula (*e.g.*, in the development of Echinoderms); or as *cœlome pouches*—pocket-like outgrowths from the endodermic lining of the gastrula-cavity (*e.g.*, in *Sagitta*, *Balanoglossus*, *Amphioxus*); or by combinations of these and other modes of origin. The mesoderm lies or comes to lie between ectoderm

and endoderm, and it lines the body-cavity, one layer of mesoderm (parietal or somatic) clinging to the ectodermic external wall, the other (visceral or splanchnic) cleaving to the endodermic gut and its outgrowths.

Origin of Organs.—From the outer ectoderm and inner endoderm, those organs arise which are consonant with the position of these two layers, thus nervous system from the ectoderm, digestive gut from the endoderm. The middle layer, which begins to be developed in "worms," assumes some of the functions, *e.g.*, contractility, which in Sponges and Cœlenterates are possessed by ectoderm and endoderm, the only two layers distinctly represented in these classes.

In a backboned animal the embryological origin of the organs is as follows:—

(*a*) *From the Ectoderm or Epiblast* arise the epidermis and epidermic outgrowths, the nervous system, the most essential parts of the sense-organs, infoldings at either end of the gut (fore-gut or stomatodæum and hind-gut or proctodæum), and probably the segmental or primary excretory duct.

(*b*) *From the Endoderm or Hypoblast* arise the mid-gut (mesenteron) and the foundations of its outgrowths (*e.g.*, the lungs, liver, allantois, etc., of higher Vertebrates), also the axial rod or notochord which precedes and is replaced by the backbone in all higher Vertebrates and persists in a few of the lower.

(*c*) *From the Mesoderm or Mesoblast* arise all other structures *e.g.*, dermis, muscles, connective tissue, bony skeleton, the lining of the body-cavity, and most probably the vascular system. This layer aids in the formation of organs originated by the other two. With it the reproductive organs are associated.

Physiological Embryology.—Of the physiological conditions of development, we know relatively little. To investigate them, is one of the tasks of the future. Why does an egg-cell form polar-bodies, how is the sperm attracted to the ovum, why does the fertilised egg-cell divide, how does the yolk affect segmentation, what are the conditions of the infolding which forms the endoderm, and of the outfolding which makes the cœlome pouches, and what do the

numerous larval stages mean? About these and many other questions the student should think.

Generalisations—(1) *The Ovum Theory or Cell Theory.*—All many-celled animals, produced by sexual reproduction, begin at the beginning again. "The Metazoa begin where the Protozoa leave off"—as single cells. Fertilisation does not make the egg-cell double; there is only a more complex and more vital nucleus than before. Moreover, all development means the division of this fertilised egg-cell and its descendant cells.

(2) *The Gastræa Theory.*—As a two-layered gastrula stage occurs, though sometimes disguised by the presence of much yolk, in the development of almost all animals, Hæckel naturally concluded that it represents the individual's recapitulation of an ancestral stage. He believes that the simplest stable, many-celled animal, was like a gastrula, and this hypothetical ancestor of all Metazoa he calls a *gastræa.* The gastrula is the individual animal's recapitulation of the ancestral gastræa. Rival suggestions have been made: perhaps the original Metazoa were balls of cells like *Volvox*, with a central cavity in which reproductive cells lay; perhaps they were like the *planula*-larvæ of some Cœlenterates—two-layered, externally ciliated, oval forms without a mouth. These and other suggestions have been made, but the gastræa theory holds the field.

The Fact of Recapitulation.—It is a matter of experience that we recapitulate in some measure the history of our ancestors. Embryologists have made this fact most vivid, by showing that the individual animal develops along a path the stations of which represent the steps of ancestral history.

(1) The simplest animals are single cells.	(1) The first stage of development is a single cell.
(2) The next simplest are balls of cells.	(2) The next is a ball of cells (blastula or morula).
(3) The next simplest are two-layered sacs of cells.	(3) The next is a two-layered sac of cells (gastrula).

Von Baer, one of the pioneer embryologists, acknowledged that with three very young embryos of higher Vertebrates (*e.g.*, rabbit, dog, man, or even reptile, bird, and mammal), before him, he could not tell one from the other. Progress in development, he said, was from a general to a special

type. In its earliest stage, every organism has a great number of characters in common with other organisms in their earliest stages; at each successive stage the series of embryos which it resembles is narrowed. The rabbit begins like a Protozoon as a single cell, after a while it may be compared to the young stage of a very simple vertebrate, after wards to the young stage of a reptile, afterwards to the young stage of almost any mammal, afterwards to the young stage of almost any rodent, eventually it becomes unmistakeably a young rabbit.

Herbert Spencer expressed the same idea, by saying that the progress of development was from homogeneous to heterogeneous, through steps in which the individual history was parallel to that of the race. But Hæckel has illustrated the idea more vividly, and summed it up more tersely than any other naturalist. His "fundamental biogenetic law" reads, "Ontogeny, or the development of the individual, is a shortened recapitulation of phylogeny, or the evolution of the race."

It is hardly necessary to say that the young mammal is never like a worm, or a fish, or a reptile. It is at most like the *young* stages of these.

Moreover, the individual life-history is much shortened compared with that of the race. I do not mean merely that the one takes place in days, while the other has progressed through ages, but stages are often skipped, and short cuts are discovered. And again, many young animals, especially those "larvæ" which are very unlike their parents, often exhibit characters which are secondary adaptations to modes of life of which their ancestors had probably no experience. In short, the individual's recapitulation of racial history is a general, but not a precise, statement of the facts.

Finally, we do not clearly understand how the recapitulation is sustained. Has the embryo a feeling for history, or some unconscious memory of the past? Recapitulation is due to no dead hand of the past, but to physiological conditions which we are unable to discover or express. The fact of recapitulation has been recently discussed with great care by Prof. Milnes Marshall,—in his Presidential Address to the Biological Section of the British Association, 1890,—published in *Nature*, September of that year.

DIAGRAM III.

THE REPRODUCTIVE CELLS, MATURATION, FERTILISATION, AND SEGMENTATION.

At the foot of the page, the maturation of the ovum is shown in A, B, C. In B, the first polar globule is being formed; in C, the second.

In the line above, (1) is a mother-sperm-cell, comparable to an ovum. In (2), it has segmented into a ball of cells or spermatocytes, which in (3) are becoming differentiated into spermatozoa.

At D, a spermatozoon is represented entering the ovum; in E, the sperm-nucleus and the reduced nucleus of the ovum are about to combine; in F, the segmentation-nucleus is formed.

In the upper part of the page, four kinds of segmentation are shown. In A and B, the segmentation is holoblastic; in C and D, it is meroblastic.

A 1 is an ovum with diffuse yolk; A 2 is the external aspect of the blastosphere; A 3 is a section of the blastosphere; A 4 is a section of the invaginated blastosphere or gastrula.

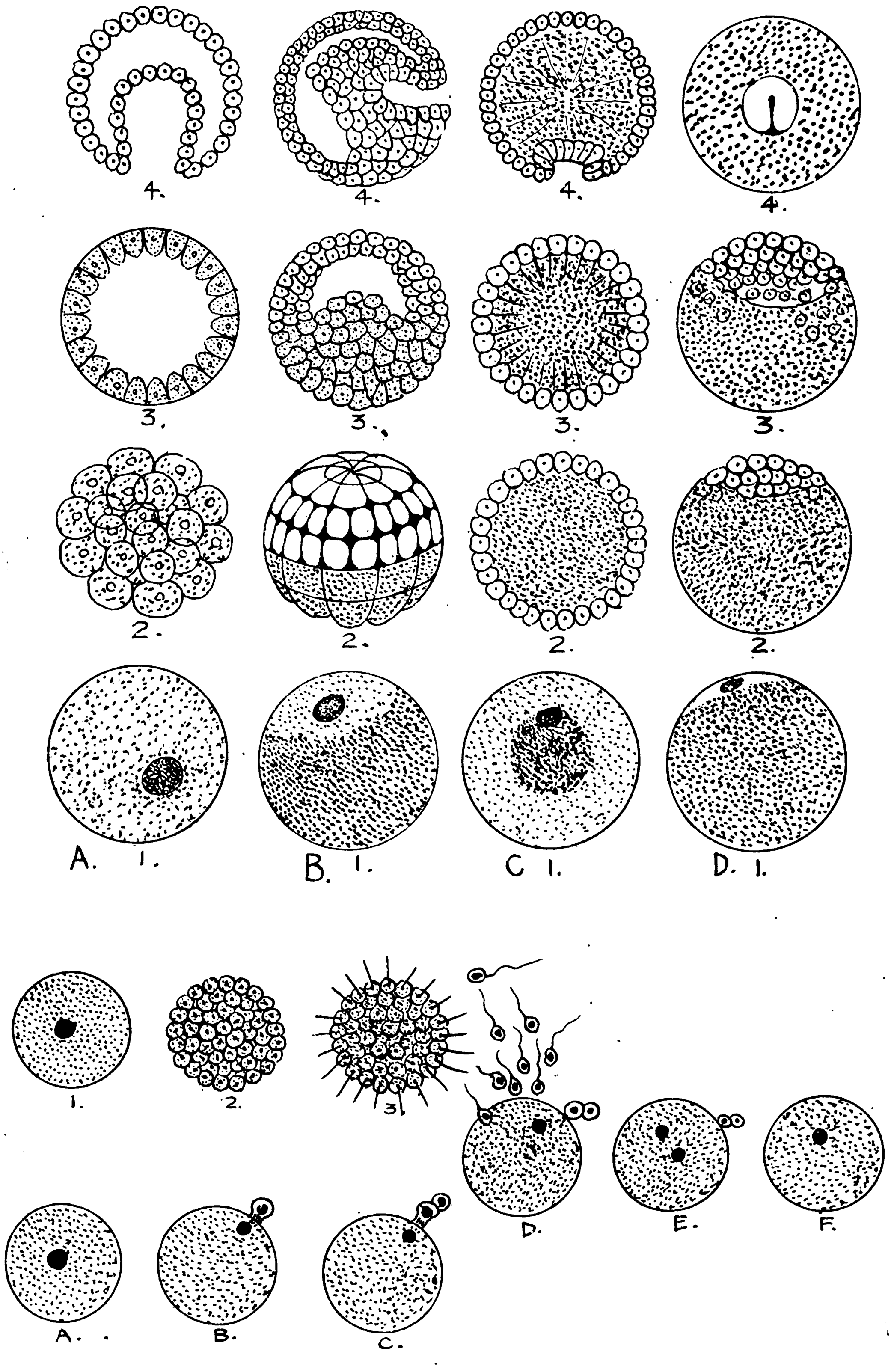
B 1 is an Amphibian ovum with the yolk towards the lower pole; B 2 is the blastosphere which results from unequal segmentation; B 3 is a section showing the segmentation-cavity; B 4 shows the beginning of the gastrula.

C 1 is an Arthropod ovum with central yolk; C 2 shows the peripheral or superficial segmentation; C 3 shows the pyramids into which the yolk becomes divided; C 4 shows the small invagination which represents the gastrula.

D 1 is an ovum with much yolk, as in Birds; D 2 shows the discoidal segmentation; D 3 shows a more advanced blastoderm; D 4 gives a slight hint of the primitive streak which appears on the embryonic area of Amniota. It corresponds to the gastrula stage.

It will be noted that the figures in each horizontal line, 1, 2, 3, 4, represent approximately similar stages. The yolk is shaded throughout.

Embryology.



III. Organic Continuity between Generations.—Heredity.

Every one knows that like tends to beget like, that offspring resemble their parents, and sometimes their ancestors (atavism). Not only are the general characteristics transmitted, but minute features, idiosyncrasies, pathological conditions, innate or congenital in the parents, may be transmitted to the offspring.

Many attempts have been made to explain this, but the first suggestion with any scientific pretensions was that the reproductive cells, which may become offspring, consist of samples accumulated from the different parts of the body. This was a very old idea, but Herbert Spencer and Charles Darwin gave it new life. According to Darwin's "provisional hypothesis of pangenesis," the reproductive cells accumulate gemmules liberated from all parts of the body. In development these gemmules help to give rise to parts like those from which they originated. This hypothesis has been repeatedly modified, but, except in the general sense that the body *may* influence its reproductive cells, "pangenesis" is discredited by most biologists.

The idea which is now accepted with general favour is, that the reproductive cells, which give rise to the offspring, are more or less directly continuous with those which gave rise to the parent. This idea, suggested by Owen, Hæckel, Rauber, Galton, Jäger, Brooks, Nussbaum, and especially emphasised by Weismann, is fundamentally important.

At an early stage in the development of the embryo the future reproductive cells of the organism are distinguishable from those which are forming the body. The latter develop in manifold variety, and as division of labour is established, lose their likeness to the fertilised ovum of which they are the descendants. The future reproductive cells, on the other hand, are not implicated in the formation of the body, but remaining virtually unchanged, continue the protoplasmic tradition unaltered, and are thus able to start an offspring which will resemble the parent, mainly because it is made of the same protoplasmic material.

A fertilised egg-cell with certain characters (*a*, *b*, *c*), develops into an organism in which these characters are

variously expressed; but if, at an early stage, certain cells are set apart, retaining the characters, *a*, *b*, *c*, in all their entirety, then each of these cells will be on the same footing as the original fertilised egg-cell, able to give rise to an organism, almost necessarily to a similar organism.

An early appearance or insulation of reproductive cells, directly continuous and therefore presumably identical with the original ovum, has been observed in the development of some "worm-types" (*Sagitta*, Threadworms, Leeches, Polyzoa), and of some Arthropods (*e.g.*, *Moina* among Crustaceans, *Chironomus* among Insects, Phalangidæ among Spiders), and with less distinctness in some other animals.

I need not explain the hypothesis by which Weismann gets over the difficulty that the reproductive cells sometimes appear relatively late in development, after differentiation has made considerable progress. It is enough to say that all the cells are descendants of the fertilised ovum, that the reproductive cells are those which retain intact the qualities of that fertilised ovum, that this is the reason why they are able to develop into offspring like the parent.

Finally, it may be noticed in connection with heredity, that there is great doubt to what extent the "body" can definitely influence its own reproductive cells. Animals acquire individual bodily peculiarities in the course of their life, as the result of what they do or refrain from doing, or as dints from external forces. The "body" is thus changed, but there is much doubt whether the reproductive cells within the "body" are affected by such changes. Weismann denies the transmissibility of any characters except those inherent or congenital in the fertilised egg-cell, and therefore denies that the influences of function and environment are, or have been, of any importance in the evolution of many-celled animals. Such influences affect the body, but do not reach its reproductive cells, and are therefore non-transmissible. Many of the most authoritative biologists are at present of this opinion. On the other hand, many still maintain, as I do, that profound changes due to function or environment may saturate through the organism, and affect the reproductive cells, and thus the race. But the whole question is under discussion. (See Article HEREDITY, in the new edition of *Chambers's Encyclopædia*.)

CHAPTER V.

PAST HISTORY OF ANIMALS.

(PALÆONTOLOGY.)

ONE of the great interests of the study of Morphology is the light that is thrown by it upon the evolution of the living world. We learn, as yet only in the most general way, how the various types are related to each other, and through what steps they have passed before their present form was arrived at. The study of form by itself must in time have led to the doctrine of evolution, and from morphology many conclusions as to the course of evolution have been drawn. These are checked by the study of the development of individual types, for each individual recapitulates to some extent in its own life-history the evolution of the race. But a more satisfactory check would be that furnished by a study of the races of living beings, which actually preceded those that now surround us. These creatures have left various traces of their existence, such as footprints, casts, and often actual portions of their bodies. As opponents of the theory of evolution have challenged its supporters to bring forward traces of former life which should clearly prove that there have been links between one type and another, it has to be confessed that the collection of such links is very imperfect. We must seek for reasons which shall explain this.

Reasons for the "Imperfection of the Geological Record."—In the first place, we must remember the great limits there are to the possibility of any animal, or even of traces of any animal, being preserved. Suppose we take those living upon the land or in the air. How many of all these will die and leave their remains in any given area? Of those

remains, how many will be destroyed by other living creatures of various kinds, or obliterated by other destroying agents,—the air, and water, and acids. If we think, we shall see that only bones, or fragments of bone, and especially teeth which are so hard, will be preserved upon the land. But what are the rocks in which we seek for remains of former life? They are the hardened, glued-together fragments of pre-existing lands, the rocks of which, slowly worn away by the ceaseless movements of water, have been carried particle by particle by the rivers to the sea or to some great lake, there to lie until some earth-movement raised them above the surface of the waters, only for the wearing away to begin once more. Thus we see how small is the chance of any trace of animals that lived upon the land being preserved; indeed, we may say that only those that happened to be drowned, or to fall when dead into some lake, sea, or river, have other than the remotest chance of leaving a trace. And further, we may remark how small is the chance that such remains will be preserved in that particular place, where, by reason of a cliff, a quarry, or a cutting, we are able to look for them. It is only those animals, then, that lived in water, that would be preserved in any number. These dying would become covered up by the constantly growing deposits of sand and mud brought down by the rivers, or if in the deep sea, by the slow growth of the ooze formed from the remains of the countless tiny creatures that inhabit the surface waters of the ocean.

But of aquatic animals we might expect a fair collection of the extinct forms; yet again we must remember,

(1) That only their hard parts, bones, teeth, and shells, are likely to be preserved to form "fossils":

(2) That of those that have been preserved, only a very small percentage can ever be discovered, since it is only where the rock is exposed that we can get at them:

(3) That many vast areas of land have as yet not been even seen by any one, while in others no thorough search for fossils has been made:

(4) That vast areas of rock are at present below the level of the sea:

(5) That many series of rocks that once existed, have been entirely destroyed by subsequent denudation:

(6) That many fossiliferous rocks have been so altered in their nature that all traces of their origin and their fossils have disappeared.

With all these causes operating against the likelihood of preservation, and of finding those forms that may have been preserved, it is little wonder if the geological record is incomplete; but such as it is, it is in general agreement with what the other evidence, theoretical and actual, leads us to expect as to the relative age of the great types of animal life. We have reason to wonder, not at the incompleteness of the geological record, but rather that the traces of past history are not even more fragmentary than they are.

Probabilities of "fossils" in the various classes of animals.—But it will be useful to note the probabilities of a good representation of extinct forms in the various classes of animals. Thus among the Protozoa the Infusoria have no very hard parts, and have therefore almost no chance of preservation, and the same may be said of forms like amœbæ; while the Radiolaria and the Foraminifera, having hard structures of lime or silica, have been well preserved. The Sponges are well represented by their spicules and skeletons. Of the Cœlenterates, except an extinct order known as Graptolites, only the various forms of coral had any parts readily capable of preservation, and remains of these are very abundant in the rocks of many ancient seas. But, strange as it may seem, some beautiful remains of jellyfish have been discovered.

Of the great series of "worms," only the tube-makers have left actual remains, the others are only known by their tracks, while of any that may have lived on the land there is no evidence.

The Echinoderms, because of their hard parts, are well represented in all their orders except the Holothurians, where the calcareous structures characteristic of the class are at a minimum.

The Crustacea, being mostly aquatic, and in virtue of their hard skin, are fossilised in great numbers.

The Arachnida and the Insects, owing to their air-breathing habit, are chiefly represented by chance individuals that have been drowned, or enclosed within tree stumps and amber.

The Mollusca and Brachiopods are perhaps better pre-

served than any other animals, since nearly all of them are possessed of a shell specially suitable for preservation.

Among the Vertebrates, some of the lowest are without scales, teeth, or bony skeleton; such forms have therefore left almost no traces.

The armoured and bony Fishes have left many representatives.

The Amphibia have bones and teeth, and those living in fresh water have left footprints as traces.

The traces of Reptilia depend upon the habits of the various orders, those living in water being often preserved, while the monstrous flying Reptiles have left many skeletons behind them.

Of the Birds, the wingless ones are best represented, and then those that live near seas, estuaries, or lakes.

The history of Mammals is very imperfect, for most of them were terrestrial. But the discoveries of Marsh and others show how much may be found by careful search. The aquatic Mammals are fairly well preserved.

"*Palæontological Series.*"—In spite of the imperfection of the "geological record," in spite of the conditions unfavourable to the preservation of many kinds of animals, it is sometimes possible to trace a whole series of extinct forms through progressive changes. Thus a series of fossilised fresh-water snails (*Planorbis*) has been worked out; the extremes are very different, but the intermediate forms link them indissolubly by a marvellously gradual series of transitions. The same fact is well illustrated by another series of fresh-water snails (*Paludina*), and not less strikingly among those extinct Cuttlefishes which are known as Ammonites, and have perfectly preserved shells. Similarly, though less perfectly, the modern crocodiles are linked by many intermediate forms to their extinct ancestors, for it is impossible to avoid calling them by that name, and the modern horse to its entirely different progenitors. For a time it was thought that palæontology yielded somewhat negative evidence in regard to progressive evolution; now, with fuller knowledge of the facts, evolutionists would be almost content to base the doctrine of descent on the palæontological evidence alone.

In a general way, it is true that the simpler animals precede the more complex in history as they do in structural

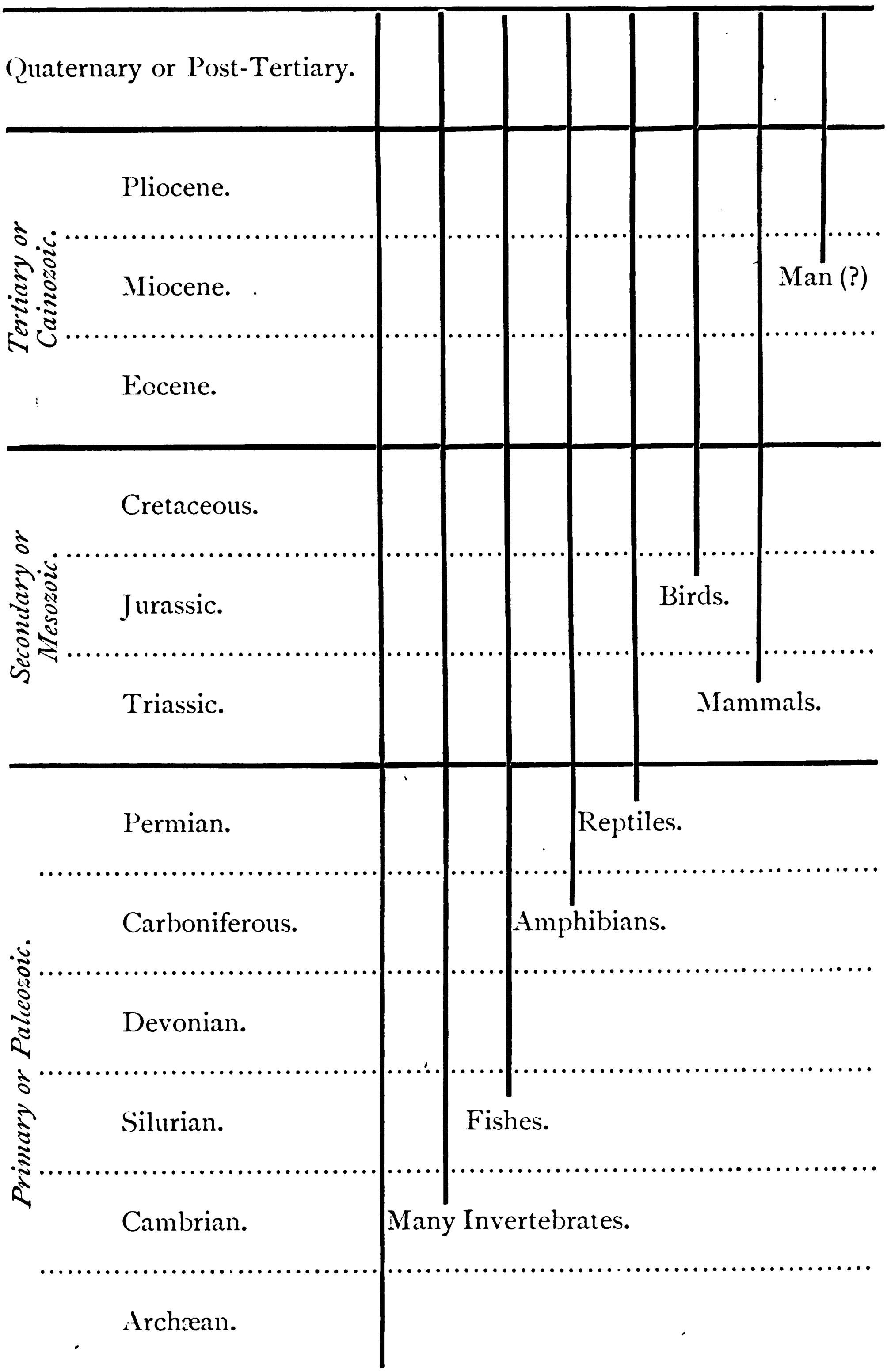
rank, but it must be remembered that though the oldest (Archæan or Laurentian) rocks bear evidence (*e.g.*, in the occurrence of marble and carbonaceous material) that forms of life existed when these rocks were formed, we have practically no means of knowing what the forms of life were. The Archæan rocks have been subjected to alterations far too serious to admit of the preservation of fossils. If this fact be fairly considered, there is no difficulty in understanding the presence of fairly complex animals in the rocks of the next great age, which is usually called Cambrian.

Extinction of Animals.—Some animals, such as some of the lamp-shells or Brachiopods, have persisted from almost the oldest ages till now, and most fossilised animals have modern representatives which we believe to be their direct descendants. That a species should become extinct need not in the least surprise us, if we believe in the "transformation" of one species into another. The extinction is more apparent than real, the species lives on in its modified descendants, "different species" though they be.

But, on the other hand, there are not a few fossil animals which have become wholly extinct, which are, in other words, without any direct descendants now alive. Such are the ancient Trilobites (probably remotely connected with our king-crab), their allies the Eurypterids, two classes of Echinoderms (Cystoids and Blastoids), many giant Reptiles, and some Mammals.

It is almost certain that there has been no sudden extinction of any animal type. There is no evidence of universal cataclysm, though local floods, earthquakes, and volcanic eruptions occurred in the past, as they do still, with disastrous results to fauna and flora. In many cases, the waning away of an order, or even of a class of animals, may be associated with the appearance of some formidable new competitors; for Cuttlefish would tend to exterminate Trilobites, just as man is rapidly and often inexcusably annihilating many kinds of beasts and birds. Apart from the struggle with competitors, it is probable that some stereotyped animals were unable to accommodate themselves to some change in their surroundings, and also that some fell victims to their own constitutions, becoming too large, too sluggish, too calcareous, in short—too extreme.

Tabular survey of the appearance of animals in time.—Such tables as that on the opposite page are apt to be very misleading, not only because our knowledge is very incomplete, but because it is very difficult to express accurately what we do know. Thus, we cannot readily give on a page any idea of the supposed relative length of the different periods; nor have we any knowledge of the very earliest ages when life began. Moreover, we have not attempted, as might be done by swellings and thinnings of the lines, to express how the different classes seem to have waxed and waned in the course of history. But the general result is clear. Many types of Invertebrates have their first records in Cambrian rocks, before Fishes appeared. Fishes precede Amphibians, Amphibians are historically older than Reptiles, and Reptiles are much older than Birds. There is no shadow of doubt on the fact that in the course of ages higher and higher types appeared.


Quaternary or Post-Tertiary.
Tertiary or Cainozoic.
Pliocene.
Miocene.
Eocene.
Man (?)
Secondary or Mesozoic.
Cretaceous.
Jurassic.
Triassic.
Birds.
Mammals.
Primary or Palæozoic.
Permian.
Carboniferous.
Devonian.
Silurian.
Cambrian.
Archæan.
Reptiles.
Amphibians.
Fishes.
Many Invertebrates.

CHAPTER VI.

GEOGRAPHICAL DISTRIBUTION OF ANIMALS.

If we are to understand animals, we must also consider their habitats.

(1.) *Pelagic Life.*—The original cradle of life was probably in the sea, and there a vast number of animals now live. Those which inhabit the open sea near the surface are conveniently called *pelagic.* Among these are many Protozoa, *e.g.*, Radiolarians, some Stinging-animals, *e.g.*, the Portuguese man-of-war (*Physalia*), small Crustaceans, an insect (*Halobates*), some free-swimming Gastropods, the sea-butterflies or winged-shells (Pteropods), free-swimming Tunicates, *e.g.*, the fire-flame (*Pyrosoma*), many Fishes, *e.g.*, herring and mackerel, besides some Birds, and cetacean Mammals. They often live in shoals, and feed on their neighbours, or on the "sea soup" of Algæ. Many are nocturnal. Most are translucent or brightly coloured, and very active.

(2.) *Littoral Life.*—From the open sea primitive animals probably passed to the shore. This has been the great school of life. Food is usually abundant, but reproduction is prolific, and thus there is great competition. Wits are sharpened, and the vicissitudes of time and tide have surely been no less influential. "It was in the littoral region," Moseley says, "that all the primary branches of the zoological family tree were formed; all terrestrial and deep-sea forms have passed through a littoral phase." The shore fauna includes many Protozoa, Sponges, Stinging-animals, such as sea-anemones and zoophytes, "worms" of all sorts, Starfishes, Crustaceans of many kinds, Molluscs, sedentary Ascidians, many Fishes, a lizard (*Amblyrhynchus*),

"sea-serpents," some turtles, many Birds, and a few Mammals, such as the Polar bear.

(3.) *Deep-Sea Life.*—From the shore contingents have doubtless gone out to the open sea whence their ancestors came, but others have probably followed outward-swept food down to the great depths. This is the most probable origin of the deep-sea fauna, which includes Protozoa, numerous horny but especially flinty Sponges, a few corals, "worms," all kinds of Echinoderms in abundance, some Molluscs and remarkable Fishes. That "animal life is present on the bottom of the ocean at all depths," was one of the important discoveries of the "*Challenger*" expedition (1872–6), which, under Sir Wyville Thomson's leadership, revealed a new zoological world. The scientific results, worked out by numerous experts, and edited by Dr. John Murray, form a monumental series of volumes, the complete importance of which we have not yet had time to appreciate, while the expedition was likewise successful in prompting other nations to similar enterprises.

"Depths beyond five hundred fathoms are inhabited throughout the world by a fauna which presents generally the same features throughout," for the conditions of life in the great abysses are very uniform. It must be a weird strange world of calm silence, without any light but gleams of phosphorescence, and necessarily without any plants. The inhabitants live on one another, but in great measure on the Protozoa and other small creatures which sink from the surface as they die. This food is probably very abundant, and the struggle for subsistence proportionally slight. The "ooze" which covers the floor of the sea, consists in great part of the shells of Diatoms, Foraminifera, Radiolarians, and Pteropods, which sink from the surface. At depths between 400 and 2000 fathoms it usually consists of the calcareous shells of Foraminifera, like those which form our chalk cliffs. This calcareous area is richest in animal life. In greater depths, before reaching which calcareous shells are dissolved, the flinty shells of Radiolarians abound; but in the greatest depths the shell-ooze is more or less completely replaced by a material usually called "red-clay."

(4.) *Fresh-water Fauna.*—Fresh water is the home of a large number of Protozoa, a sponge (*Spongilla*), *Hydra* and

two or three allies, a medusa (!) (*Limnocodium*), many "worms" (*e.g.*, Planarians, Annelids like *Nais* and *Tubifex*, Rotifers etc.), many small Crustaceans and the large crayfish, some Insects, Bivalves like *Anodon*, *Unio*, *Cyclas*; snails like *Lymnæus*, *Paludina*, *Planorbis*; many Fishes; Amphibians, in their youth at least; some Reptiles, Birds, and Mammals.

In lakes there are not many different kinds of animals except near the shore. Neither in the depths nor at the surface is the animal population diverse. Small Crustaceans, Rotifers, and Infusorians are commonest, but there are not many different genera, though Prof. Zacharias and other enthusiasts are rapidly increasing our appreciation of this fauna.

A few fresh-water animals have come from the land, others have gradually spread from the sea up estuaries and rivers, probably most were originally marine, for many lakes are the residues of inland seas. The young stages of many have interesting adaptations, which obviate the risks of being swept away by currents.

(5.) The *terrestrial fauna* probably arose by gradual migrations from the shore landwards. It includes some Protozoa which live in damp earth; leeches and earthworms; a few Crustaceans (land-crabs and wood-lice); many Myriopods, Insects, and Spiders; snails and slugs; adult Amphibians; besides most Reptiles, Birds, and Mammals.

But some terrestrial animals have become more or less aërial, notably Insects, Birds, and Bats.

Moreover, not a few animals from the shore, or from fresh water, or from land have found a very different kind of habitat as parasites on or in other organisms.

Geographical Areas.—The terrestrial fauna varies in different countries, and has often varied in the same country, as one kind of climate has succeeded another through the long past.

From their original homes animals have spread mostly by active migration, but also with the help of wind and water-currents and other dispersing powers. As they have spread, they have varied, according to their nature and the force of changed circumstances, and the degree of their isolation.

The geographical position of the original birth-places, the

physical possibilities of dispersal, the climatic, nutritive, and competitive conditions of different areas, besides the great changes of the earth's surface and of consequently isolated evolution, explain in a general way why the fauna of Europe is very different from that of South America, or the fauna of Africa from that of Australia.

In the course of our study we shall notice some of the more striking facts of geographical distribution, meanwhile we shall simply define the limits of the great regions into which the earth is divided by zoologists. Schmarda, Murray, Wallace, Sclater, and others have established these regions mainly with reference to birds and mammals, but there is no doubt that the divisions are in a general way consistent for most animals.

I shall simply quote a paragraph from Professor Angelo Heilprin's work—*The Geographical and Geological Distribution of Animals* (Internat. Sci. Series. London, 1887), a most valuable book for the student, especially as it considers distribution in space and time together.

"By most naturalists the terrestrial portion of the earth's surface is recognised as consisting of six primary zoological regions, which correspond in considerable part with the continental masses of geographers. These six regions are :

"1. The *Palæarctic*, which comprises Europe, temperate Asia (with Japan), and Africa north of the Atlas Mountains; also Iceland, and the numerous oceanic islands of the North Atlantic :

"2 The *Ethiopian*, embracing all of Africa south of the Atlas Mountains, the southern portion of the Arabian Peninsula, Madagascar, and the Mascarene Islands, and which, consequently, nearly coincides with the Africa of geographers :

"3. The *Oriental* or Indian, which embraces India south of the Himalaya, Farther India, Southern China, Sumatra, Java, Bali, Borneo, and the Philippines :

"4. The *Australian*, comprising the continent of Australia, with Papua or New Guinea, Celebes, Lobok, and the numerous islands of the Pacific :

"5. The *Nearctic*, which embraces Greenland, and the greater portion of the continent of North America (excluding Mexico) :

"6. The *Neotropical*, corresponding to the continent of South America, with Central America, the West Indies, and the greater portion of Mexico."

Professor Heilprin makes several modifications on this scheme of distribution: (*a*) uniting Palæarctic and Nearctic in one Holarctic realm; (*b*) establishing a special Polynesian realm for the scattered island groups of the Pacific; and (*c*) defining three transition regions, (1) around the Mediterranean, intermediate between East Holarctic, Ethiopian, and Oriental, (2) Lower California between Western Holarctic and Neotropical, and (3) the Austro-Malaysian islands lying to the east of Bali and Borneo, inclusive of the Solomon islands, a region intermediate between Oriental, Australian, and Polynesian.

It may be convenient to map out the divisions as follows:—

(Arctic.)

NEARCTIC. PALÆARCTIC.

Holarctic.

Transition to | Transition to | ORIENTAL.

Transition to *Polynesian* and to

Polynesian—NEOTROPICAL. ETHIOPIAN. AUSTRALIAN.

(Antarctic.)

CHAPTER VII.

THE EVOLUTION OF ANIMALS.

(Ætiology.)

I. The Doctrine of Descent.

When we ask, as we are bound to ask, how the living plants and animals that we know came to be what they are—very numerous, very diverse, very beautiful, marvellous in their adaptations, harmonious in their parts and qualities, and approximately stable from generation to generation,—we may possibly receive three answers. According to one, the plants and animals that we know have always been as they are; but this is obviously contradicted by the record in the rocks, which contain the remains of successive sets of plants and animals very different from those which now live upon the earth. By another, it is supposed that each successive fauna and flora was destroyed by mundane cataclysms, to be replaced in due season by new creations, by new forms of life which arose after a fashion of which the human mind can form no conception. The third answer is, that the present is the child of the past in all things, that the plants and animals now existing arose by a natural evolution from simpler pre-existing forms of life, these from still simpler, and so on back to a simplicity of life such as that now represented by the very lowest organisms.

This third theory is really an old one; it is merely man's application of his idea of human history to the world around him. It was maintained with much concreteness and power by Buffon (1749), by Erasmus Darwin (1794), and by Lamarck (1801). But in spite of the labours of these thoughtful naturalists and of many others, the general idea of the natural descent of organisms from simpler ancestors,

was not received with much favour till Darwin, in his "Origin of Species" (1859), made it current intellectual coin. By his work and by that of Spencer, Wallace, Hæckel, and many others, the doctrine of descent, the general fact of evolution, has been established, and is now all but universally recognised.

The chief arguments which Darwin and others have elaborated in support of the doctrine of descent, according to which organisms have been naturally evolved from simpler forms of life, may be ranked under three heads—(*a*) structural, (*b*) physiological, (*c*) historical. I shall not restate the arguments, but content myself with reminding you of their nature.

Evidences of Evolution.

(*a*) *Structural.*—(1) There are said to be about two million living animals of different species, that is to say, of different kinds which are not readily fertile with one another. These species are connected together by varieties, which make strict severance often impossible; they can be rationally arranged in genera, orders, families, and classes, between which there are sometimes remarkable connecting links; there is a gradual increase of complexity from the Protozoa upwards along various lines of organisation; it is possible to rank them all on a genealogical tree. A little practical experience makes one feel that the facts of classification favour the idea of common descent.

(2) Throughout vast series of animals, we find in different guise essentially the same parts, twisted into most diverse forms for different uses, but yet referable to the same fundamental type. It is difficult to understand this "adherence to type," this "homology" of organs, except on the theory of natural relationship.

(3) There are many rudimentary organs in animals, especially in the higher animals, which remain very slightly developed, and which often disappear without having served any apparent purpose. Such are the "gill-slits" or "visceral clefts" in Reptiles, Birds, and Mammals, the teeth of young whalebone whales, or of embryonic parrots, the pineal body (a rudimentary eye) in Vertebrates, etc., etc. Only on the

theory that they are vestiges of structures which were of use in ancestors are these rudiments intelligible. They are relics of past history like the unpronounced letters in many words.

(*b*) *Physiological.*—(1) Observation shows that animals are to some extent plastic. In natural conditions they vary in the course of several generations or even in a lifetime. This is especially the case if one section of a species be in any way isolated from the rest, or if the animals be subjected in the course of their wanderings to novel conditions of life. Even apart from notably changed circumstances, moreover, animals exhibit variations from generation to generation.

(2) The evidence from domesticated animals is very precise and convincing. By careful interbreeding of varieties which pleased his fancy or suited his purposes, man has produced numerous breeds of horses, cattle, sheep, and dogs, which are often distinguished from one another by structural differences more profound than those which separate two natural species. In great measure, however, domestic breeds are fertile with one another, while different species rarely are. The numerous and very diverse breeds of domestic pigeons, which are all derived from the rock-dove (*Columba livia*), vividly illustrate the plasticity or variability of organisms.

(3) It sometimes happens that the offspring of an animal resemble not so much the parent as some other form believed or known to be ancestral. Thus a blue pigeon like the ancestral *Columba livia* may be hatched in the dove-cot, a foal may appear with zebra-like stripes, and in times of famine children may be born who are in some ways ape-like. Such atavisms or reversions are not readily intelligible except on the theory of descent.

(*c*) *Historical.*—(1) Among the extinct animals disentombed from the rocks, many form series by which those now existing can be linked back to simpler ancestors. Thus the ancient history of horses, crocodiles, and cuttlefish is known with a degree of completeness which makes it almost certain that the simpler extinct forms were in reality the ancestors of those which now live. Moreover, that many connecting links have been discovered in the rocks, and that

the higher animals gradually appear in successive periods of the earth's history, are strong corroborations of the theory.

(2) It is less easy to state in a few words, how the facts of geographical distribution, or the history of the diffusion of animals from centres where the presumed ancestral forms are or were most at home, favour the doctrine of descent.

(3) The individual life-history of an animal— often strangely circuitous or indirect—is interpretable as a modified recapitulation of the probable history of the race. Every animal starts as a Protozoon ; the morula and gastrula stages correspond to the presumable beginnings of multicellular life. The embryo mammal is at one stage somewhat like a young fish, at another like a young reptile ; even in details, the recapitulation, if such we may term it, is sometimes faithful.

II. The Theory of Evolution.

The doctrine of descent is now almost universally recognised ; but there is much uncertainty in regard to the way in which the evolution has been brought about. The fact of evolution is admitted, while debate goes on with regard to the factors. With the exception of Alfred Russel Wallace and a few others, who postulate spiritual influxes to explain the beginning of consciousness and the higher human qualities, evolutionists are agreed in trying to explain the evolution of plants and animals as a continuous natural process, the end of which was implicit in the beginning. In so doing they are following the method of analysis,—trying to explain things in their lowest terms. As the biologist's lowest term is living matter, about which our most certain knowledge is that it can in favourable circumstances *think*, there is no reason to call the evolutionist's analysis "materialistic"—if anything opprobrious be meant by that adjective. Nay more, even if he knew the chemical and physical secret of living matter,—an advance not in the least degree imminent at the present rate of progress, he would know but a marvellous kind of ethereal motion, of which again we have surest knowledge in our brains when we think and feel. In short, the common denomin-

ator of biologist and physicist alike is as inexpressibly marvellous as the philosopher's greatest common measure.

There are at least two great problems in evolution :—

(A) How do changes or variations arise?

(B) How do these variations become new, well-adapted, progressive species?

A. *The Primary Factors in Evolution*—which will account for the origin of variations.

It is well to recognise that this is the fundamental problem. Unless we can give some theory of the origin of variations, we have no material for further construction. Unfortunately we are very ignorant about the whole matter. But, in the first place, it is quite certain that the environment in the widest sense must be the primary cause of changes in animals. So far almost all naturalists are agreed. Thus Herbert Spencer says, "The action of the environment is the primordial factor in organic evolution," and Weismann traces the origin of variations in the long run to the action of the environment upon the simplest organisms. By the environment we mean all external influences —mechanical, chemical, physical; pressure, moisture, aëration, heat, light, and also food. [It is indeed possible that there are environmental influences of which our senses are unaware,—the "spiritual influxes" of which Wallace speaks, but these are obviously beyond the scope of scientific analysis.] *

That all variations are ultimately due to the action of the environment in the widest sense, we regard as an axiom. But in regard to the direct conditions of organic change, naturalists are or ought to be very uncertain. I shall state the possibilities.

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* It seems to me desirable to avoid talking about the "principles of evolution," *e.g.*, as variability, heredity, and natural selection, or as variability, heredity, isolation. Not only are words like "principle" used in the loosest possible way, but they suggest a conclusiveness which certainly does not exist, and they are apt to become intellectual fetishes. Variability is only a term for the tendency organisms have to vary, the conditions of variation being numerous and obscure. Similarly, heredity is only a term for the relation of organic continuity between successive generations.

(1.) *Environmental.*—Variations produced by the direct action of external influences (emphasised by Buffon, Treviranus, Semper, and others.)

(2.) *Functional.*—Variations produced as the results of use and disuse, or by change of function (emphasised by Erasmus Darwin, Lamarck, and the "Neo-Lamarckians").

(3.) *Organismal, Constitutional, or Congenital.*—Variations not directly traceable to (1) or (2), but resulting from the inequilibrium of the protoplasm :
  or from the tendency to preponderance of anabolic or katabolic processes (Geddes) :
  or from pathological change (Sutton) :
  or from the internal complexity of the organism, the "struggle of parts within the organism" (Roux) :
  or from the predominance of an accessory over a principal function (Dohrn) :
  or from the rhythm between vegetative and reproductive preponderance (Geddes) :
  or from the stimulus that one part gives to another (Kleinenberg) :
  or from the tendency to "cumulative growth" in definite directions (Eimer) :
  or from the intermingling of two different living plasmas in fertilisation (Weismann).

Congenital variations are regarded by most Darwinians as numerous, *indefinite*, arbitrary, "fortuitous," "spontaneous," without any necessary connection with the experience, habits, needs, or external surroundings of the animal.

According to a minority, variations occur in a few *definite* directions, necessarily determined by the constitution, habits, and surroundings of the organism or of its ancestors.

B. *The Secondary Factors in Evolution*, as the result of which variations become new, well-adapted, and progressive species.

(1.) *Natural Selection.*—Though Charles Darwin believed in the efficacy of external influences and of use and disuse as factors in evolution, the distinctive contribution which he

and Alfred Russel Wallace made to the theory of evolution, was to show how natural selection, acting upon indefinite variations, might give rise to new species and adaptations. "Natural selection has been the main, but not the exclusive, means of modification."

The Darwinian theory may be thus summarised: All organisms produce offspring on the whole like themselves, but also exhibiting new and individual features. As the result of the severe struggle for existence, only a small percentage of offspring survive to become reproductive adults. The survivors are those whose variations enable them to gain some advantage over their fellows in the struggle for food, mates, and other conditions of well-being. A fit variation not only secures the survival of its possessors, but is transmitted from parents to offspring, and is intensified from generation to generation. By this process of natural selection of advantageous variations, continued for many generations, the modification of species has been effected.

There is no doubt that the variations on which Darwin mainly relied were constitutional or congenital variations, whose transmissibility is quite certain. He rarely speculated as to their origin, but believed it to be a fact that "spontaneous," "indefinite," "fortuitous" variations constantly occurred. Darwin also believed in the importance of sexual selection, in which the females choose the more attractive males, which, succeeding in reproduction better than their neighbours, tend to transmit their qualities to their numerous male heirs. But this and other forms of reproductive selection may be regarded as special cases of natural selection, and require no particular emphasis. Nor is the importance of sexual selection admitted by so great an authority as Wallace.

(2.) "*Isolation.*"—Under this title Romanes, Gulick, and others include the various ways in which free intercrossing is prevented, by the geographical separation of the members of a species, or by a reproductive variation causing mutual sterility between two sections of a species living on a common area. "Without isolation, or the prevention of free intercrossing, organic evolution is in no case possible. Isolation has been the universal condition of modification. Heredity and variability being given, the whole theory of

organic evolution becomes a theory of the causes and conditions which lead to isolation" (Romanes).

Cumulative Effect of Definite Variations.

According to some other naturalists (Buffon, Lamarck, Treviranus, Erasmus Darwin, Mivart, Cope, Eimer, and Geddes), definite variations due to the sustained action of the environment, or to persistent change of function, or to internal conditions of growth, may accumulate in the course of generations, so that new, well-adapted, and progressive species are evolved.

In regard to environmental and functional variations, however, it is at present difficult to decide as to the degree in which they are transmissible.

Struggle for Existence.

Geddes especially has protested against exaggerating the importance of the individual struggle for existence, maintaining that some of the most important steps in evolution have been due to the subordination of nutritive to reproductive activities, of self-preserving to species-maintaining functions, of egoism to altruism. Kropotkin has also shown with much carefulness that mutual aid is exhibited by many animals, and that it modifies and ennobles the struggle for material subsistence.

It should be remembered that Darwin intended the phrase "struggle for existence" to be used "in a wide and metaphorical sense." He did not mean it to be restricted to individualistic competition for food. He meant it to include all endeavours for the well-being both of the individual and the offspring.

Moreover, as natural selection simply means that useful variations succeed and that the unfit are eliminated, it justifies altruistic endeavour no less—in some cases more—than egoistic struggle.

It seems to me quite possible to combine all the theories of evolution : the difficulty is to know in what proportions.

Meanwhile I suggest the following balance-sheet of opinions :—

SUMMARY OF EVOLUTION THEORIES.

Variations all ultimately due to External Influences.

Primary Factors.	Direct action of the environment produces environmental variations,	Organismal, constitutional, congenital, or germinal variations may be either definite or indefinite.		Use and disuse, or change of function, produce functional variations	Origin of Variations.
	which if transmissible	(certainly transmissible)		which if transmissible	
Secondary Factors.	may accumulate as environmental modifications of species. *	By the persistence of the original conditions these may grow into new species. *	By natural selection in the struggle for existence these may give rise to new species.	may accumulate as functional modifications of species. *	Origin of Species.
	All cases	may be affected by		" isolation.	

The process of natural selection will affect all cases, but is less essential for those marked *.

SOME NOTES ON BOOKS.

Those for whom this volume is primarily intended,—students who are beginning the study of Zoology as part of a scientific and medical curriculum, will find the following four books of great service:—F. Jeffrey Bell's *Comparative Anatomy and Physiology* (Lond. 1887); C. Lloyd Morgan's *Animal Biology* (Lond. 1889); *A Course of Elementary Instruction in Practical Biology*, by T. H. Huxley and H. N. Martin, revised edition by G. B. Howes and D. H. Scott (Lond. 1888); and *A Course of Practical Zoology*, by A. Milnes Marshall and C. H. Hurst, 2nd Ed. (Lond. 1888).

Among text-books, Huxley's two volumes on the *Anatomy of Invertebrate* and *Vertebrated Animals* (Lond. 1877 and 1871), occupy the highest plane, but they require to be re-edited. Useful in particular ways are the works of Claus, *Grundzüge der Zoologie*, Marburg, 1880–2 (untranslated), and his smaller text-book (trans. by A. Sedgwick, 2 vols., Lond. 1884–5), and the text-books of A. S. Packard, and of H. Alleyne Nicholson. As a modern introduction to the problems of classification, W. A. Herdman's *Phylogenetic Classification of Animals* (Lond. 1885) will be found at once terse and clear.

Works on Comparative Anatomy:—Gegenbaur's (trans. by F. Jeffrey Bell, Lond. 1878); Wiedersheim's (trans. by W. N. Parker, Lond. 1886), and his unabridged and untranslated volume; Lang's re-edition of O. Schmidt's *Vergleichende Anatomie* (in progress, Jena, and being translated); Hatschek's smaller work (also in progress, Jena, and untranslated). A treatise on comparative physiology is hardly possible at present, but the senior student should make himself acquainted with Krukenberg's *Vergleichend-Physiologische Studien* and *Vorträge* (Heidelberg, 1881–9).

For the practical study of Invertebrates, we have now a complete manual in French or German, by Vogt and Yung (*Traité d'Anatomie comparée pratique* (Paris 1885–90); or *Lehrbuch der praktischen Vergleichenden Anatomie* (Braunschweig 1885–90), which is being continued by a similar treatment of Vertebrates. W. K. Brooks' *Handbook of Invertebrate Zoology for Laboratories and Sea-side Work* (Boston, 1882), is very valuable. T. J. Parker's *Zootomy* (Lond. 1884), is indispensable to those who wish to make a thorough practical study of the common vertebrate types.

An atlas will help the student greatly, if he does not use it too much.

G. B. Howes, *Atlas of Practical Elementary Biology* (Lond. 1885).

A. de Vayssière, *Atlas d'Anatomie comparée des Invertébrés* (Paris 1889).

W. R. Smith and J. S. Norwell, *Illustrations of Zoology: Vertebrates and Invertebrates* (Edin. 1889).

Works on Embryology:—

F. M. Balfour, *Comparative Embryology* (2 vols., Lond. 1880-81).

M. Foster and F. M. Balfour, *The Elements of Embryology.* 2nd Ed. by A. Sedgwick and W. Heape (Lond. 1883).

A. C. Haddon, *Introduction to the Study of Embryology* (Lond. 1887).

O. Hertwig, *Lehrbuch der Entwicklungsgeschichte des Menschen und der Wirbelthiere.* (2 Ed. Jena, 1888., cf. French ed. by Julin.)

E. Korschelt and K. Heider, *Lehrbuch der Vergleichenden Entwicklungsgeschichte der Wirbellosen Thiere.* (1st part, Jena, 1890.)

Works on Palæontology:—

H. A. Nicholson and R. Lydekker, *Manual of Palæontology* (2 vols., Lond. and Edin. 1889).

K. A. von Zittel's *Handbuch der Palæontologie* (in progress, Munich and Leipzig).

M. Neumayr, *Die Stämme des Thierreichs* (vol. I., Vienna and Prag, 1889).

For information as to the geographical distribution of animals see:—

A. R. Wallace, *Geographical Distribution* (2 vols., Lond. 1876).

A. Heilprin, *The Geographical and Geological Distribution of Animals.* (Internat. Sci. Ser. Lond. 1887.)

W. Marshall, in Berghaus' *Physikal Atlas* (Leipzig, 1887).

As works of reference, the following are useful:—

Bronn's *Klassen und Ordnungen des Thierreichs* (a series of volumes still in progress, Leipzig).

Leunis, *Synopsis des Thierreichs* (Hanover, 1886). (Useful for the identification of animals.)

The Zoological Articles in the *Encyclopædia Britannica* (some of which by E. Ray Lankester and others are published separately).

W. Hatchett Jackson's edition of Rolleston's *Forms of Animal Life* (Oxford, 1888).

For records of progressive research, I may refer the student to the *Journal of the Royal Microscopical Society* (edited by F. Jeffrey Bell), which is published every other month, and gives summaries of recent researches; the annual *Zoological Record* (edited by F. E. Beddard), which catalogues all the work of the preceding year; the most important British Journal,—*The Quarterly Journal of Microscopical Science* (edited by E. Ray Lankester and others), and of course *Nature*, in which valuable summaries and discussions are often found.

Students naturally wish to supplement their knowledge of the anatomy and physiology of animals with information about their habits, and for this purpose there are three excellent works,—*Cassell's Natural History*, edited by P. Martin Duncan (6 vols., Lond. 1882); *The Standard* or *Riverside Natural History*, edited by J. S. Kingsley (6 vols., Lond. 1888), and Brehm's *Thierleben*, of which a new (3rd) edition is at present in progress (10 vols., Leipzig and Vienna.) Those who read German will also find in Carus Sterne's (Ernst Krause's) *Werden und Vergehen* (3rd ed., Berlin 1886), the most successful attempt yet made to combine in one volume, a history of the earth and its inhabitants.

Those interested in the psychology of animals should begin with the works of G. J. Romanes, *Animal Intelligence*, and *Mental Evolution of Animals*, with Sir John Lubbock's *Senses of Animals*, and with the recently published book on *Animal Life and Intelligence*, by C. Lloyd Morgan.

Of introductions to the study of Evolution, there is no better than A. R. Wallace's *Darwinism* (Lond. 1889), and the philosophic student should not omit reading P. Geddes's articles *Biology* and *Evolution* in *Chambers's Encyclopædia*. The great work on the history of Zoology is that of J. V. Carus, *Geschichte der Zoologie* (Munich, 1872), but a short sketch wil be found in E. Ray Lankester's article *Zoology* in the *Encyclopædia Britannica*.

A guide both to the more popular and to the more philosophical literature of Zoology will be found in my *Study of Animal Life* (Lond. 1891.

CHAPTER VIII.

PROTOZOA—THE SIMPLEST ANIMALS.

Most of the simplest animals or Protozoa are very small unit masses of living matter, or single cells, which usually differ from plants in their way of feeding. Most of them feed on small plants or other Protozoa, or on the débris of larger living things, and not a few are parasitic. Most of them live in water, but many can endure dryness for some time. In one set (Rhizopods) the living matter is without any rind, and flows out in more or less changeful threads and bulgings, by the movements of which the animals engulf their food and glide along. The others have a definite rind, which in a very large number (Infusorians) bears rapidly motile lashes or cilia, but in a minority (Gregarines) is without any obvious locomotor structures. But these three states may occur in the life of one form; in fact, each of the three great classes is marked by the *predominant*, and not by the exclusive occurrence of the rhizopod-like, or the infusorian-like, or the gregarine-like phase of cell-life. Many have an external framework of lime, flint, or other material, while within the cell there is a special kernel or nucleus, or there may be several. There are also other less constant structures. The Protozoa multiply by dividing into two daughter units, or into a large number; and two individuals often unite temporarily, or permanently, in conjugation, which is analogous to the union of ovum and spermatozoon in higher animals.

Let us revise these facts in greater detail.

Protozoa and Metazoa.—According to the cell theory or doctrine, first clearly stated by Schwann and Schleiden

in 1838–9, all but the simplest plants and animals are built up of many unit masses of living matter or cells. The Protozoa are, with few exceptions, unicellular; all other animals (Metazoa) are multicellular. A Protozoon is therefore comparable to a blood-cell, a muscle-cell, or a ciliated cell,—to *one* of the many units which make up a higher animal. We may compare a rhizopod with a white blood corpuscle, an infusorian with one of the ciliated cells lining the windpipe, a gregarine with a degenerate muscle-cell.

But there is this difference, a single-celled Protozoon is an independent organism complete in itself. Within the compass of its unit mass, all the usual functions of contractility, irritability, digestion, secretion, respiration, and excretion, are discharged; while in a higher animal, in which division of labour has been established, each cell is more or less dependent upon its neighbours, and its functions are restricted or specialised in range. A Protozoon is a cell which is physiologically complete in itself.

Moreover, it was soon realised, as a corollary of the cell theory, that every Metazoon begins to develop from the repeated division of an egg-cell or ovum, which has been fertilised in most cases by a male-cell or spermatozoon. It became evident that the Protozoa correspond to these reproductive cells. The Protozoa are comparable to the young ova, or to the primitive-male-cells of higher animals. But the primitive-male-cell of a higher animal divides into a number of spermatozoa, which cling together for a while, separate, and are liberated from the body, mostly to die; while the numerous cells into which a Protozoon may divide, go apart and live independent lives. Or again, the young ovum of a higher animal increases in size, makes a preliminary attempt at division on its own account, but dies in most cases unless it be united with a male-cell. When thus fertilised, it divides repeatedly, and the result is an embryo of coherent cells; whereas the units into which a Protozoon divides usually part company at once. In short, the Protozoa do not form a "body"; "they leave off where higher animals begin."

It has been necessary to insert many saving clauses in speaking of the unicellular character of Protozoa, for this

reason, that some Protozoa divide and yet cohere, forming loose colonies of cells. In these, there is little or no division of labour; we can hardly call them "bodies"; yet they consist of many cells in loose union. Such colonies are found among some of the very simplest of the Protozoa, as well as among Rhizopods, and among Infusorians.

Plants and Animals.—Plants live a life fundamentally similar to that of animals. Like animals, plants breathe and digest, and they often move and feel; the higher forms are built up of many cells, and spring from a fertilised egg-cell; the chemist finds many substances in plants, which occur in animals also.

Thus there is no absolute distinction between plants and animals; they represent divergent branches of a V-shaped tree of life. It is easy to distinguish extremes, like bird and daisy, less easy to contrast sponge and mushroom, well nigh impossible to decide whether some very simple forms, which Hæckel called "protists," have a bias towards plants or towards animals. But the food which most plants absorb is cruder or chemically simpler than that which animals are able to utilise. Plants derive the carbon they require from the carbonic acid gas of the air, whereas only a few green animals have this power. Almost all animals depend on the sugar, starch, and fat already made by other animals, or by plants. As regards nitrogen, most plants derive this from simple nitrates, absorbed along with water by the roots; whereas animals obtain their nitrogenous supplies from the complex proteids formed within other organisms. Most plants, therefore, feed at a lower chemical level than do animals, and it is very characteristic of them, that in the reduction of carbonic acid, and in the manufacture of starch and proteids, the kinetic energy of sunlight is transformed by the living matter into the potential chemical energy of complex food-stuffs. Animals, on the other hand, get their food ready-made; they take the pounds which plants have, as it were, accumulated in pence, and they spend them. For it is very characteristic of animals that they convert the potential chemical energy of food-stuffs into the kinetic energy of locomotion and other activities. In short, the great distinction—an average one at best—is that most animals are more active than most plants. But as the

Some Exceptions.	Characteristics of Animals.	Characteristics of Plants.	Some Exceptions.
Some Protozoa and parasites simply absorb.	They feed on more or less solid food.	They absorb soluble food.	
Some green Protozoa (etc.?) seem to be able to utilise carbonic acid as plants do.	They obtain the requisite carbon from starch, sugar, fat, etc., made by plants or by other animals.	They obtain the requisite carbon from carbonic acid gas in the air or water.	Carnivorous plants, Fungi, and some parasites find other sources of carbon-supply.
Again, some Protozoa are probably able to feed like plants.	They obtain the requisite nitrogen from nitrogenous compounds not simpler than the proteids, made by other organisms. Most of them are known to get rid of nitrogenous waste-products.	They obtain the requisite nitrogen from simple nitrogenous compounds, especially the nitrates of the soil. They do not get rid of nitrogenous waste-products.	Again, carnivorous plants, Fungi, and some parasites are in part exceptional in their nutrition.
A few, *e.g.*, some Protozoa, the fresh-water sponge, *Hydra viridis*, have green pigment closely analogous or identical with chlorophyll.	They have very rarely any chlorophyll.	The majority possess chlorophyll, the green pigment by aid of which the living-matter utilises the energy of sunlight, in reducing carbonic acid (with liberation of oxygen), and in building up complex substances.	Fungi and some parasites have no chlorophyll.
Cellulose seems to occur in some Infusorians, and forms most of the tunic or cuticle of the passive sea-squirts or ascidians.	The component cells often have no very definite cell-walls, rarely have them of material demonstrably different from the cell-substance, and almost never show any trace of cellulose.	The component cells are walled in by cellulose, a material chemically allied to starch.	Some simple plants have for a time at least naked cells.
	Marked division of labour among the cells is characteristic.	The cells exhibit, on an average, much less division of labour.	
	They utilise food-material already worked up by plants or by other animals; they convert this potential energy into kinetic energy in locomotion and external work; they are characteristically oxidisers, are predominantly active, and show in the vital changes associated with their living matter or protoplasm, a *relative* preponderance of disruptive, down-breaking, or "katabolic" processes.	They build up crude, chemically simple food-material into living complex substances; they convert the kinetic energy of sunlight into the potential chemical energy of these complex substances; they are characteristically reducers (of carbonic acid), expend comparatively little energy in motion or external work, are predominantly passive, and show in the vital changes associated with their living matter or protoplasm a *relative* preponderance of constructive, up-building, or "anabolic" processes.	

time-honoured "distinctions between plants and animals" are apt to be wearisome, I have condensed them in a table.

General Classification.—Since the Protozoa are for the most part single cells, it is evident that their classification should be harmonious with that of the units in a higher animal. There are three series—(*a*) those in which the living matter flows out in changeful threads, or "pseudopodia," as in the common *Amœba*, which we compare with the white blood-corpuscles or leucocytes, many young ova, and other "*amœboid*" cells of higher animals; (*b*) those in which the units, bounded by a definite rind, bear motile lashes (cilia or flagella), as in the common *Paramœcium*, which we may liken to the cells of *ciliated* epithelium, or to the active spermatozoa of higher animals; (*c*) those in which the units, again with a rind, have no motile processes or outflowings, viz., the parasitic Gregarines, which we may compare to degenerate muscle-cells, or to mature ova, or to "*encysted*" passive cells in higher animals.

Moreover, this threefold classification represents the three physiological possibilities—(*a*) the amœboid units, neither very active nor very passive, forming a median compromise; (*b*) the ciliated Infusorians, which are usually smaller, showing the result of a relative predominance of expenditure; (*c*) the encysted Gregarines representing an extreme of sluggish passivity.

But, as Geddes and others have shown, the cells of a higher animal often pass from one phase to another,—the young amœboid ovum accumulating yolk becomes encysted, the ciliated cells of the windpipe often to our discomfort sink into amœboid forms. The same is true of the Protozoa; thus in various conditions the ciliated or flagellate unit may become encysted or amœboid, while in the very simplest forms, such as *Protomyxa*, there is a "cell-cycle" in which all the phases occur in one life-history.

Therefore our classification must read as follows:—

(*a*) Rhizopods,—which are predominantly amœboid, and possess changeful but sluggish outflowing processes, either blunt or thread-like. They represent an equilibrium or mean between the following extremes.

(*b*) Infusorians,—which are predominantly ciliated. They exhibit ascendant activity.

(*c*) Gregarines,—which are predominantly encysted, and have no locomotor processes. They illustrate predominant passivity.

It is also important to notice Ray Lankester's division of the Protozoa into naked and clothed forms (Gymnomyxa and Corticata), the latter with the unit enclosed in a definite rind, the former with the living matter unensheathed. The Gymnomyxa include the primitive forms, and the Rhizopods; the Corticata include the two extremes—Gregarines and Infusorians.

CLASSIFICATION OF PROTOZOA.

(CORTICATA.)	(GYMNOMYXA.)	(CORTICATA.)
Predominantly lashed and active.	Predominantly amœboid.	Predominantly encysted and passive.
INFUSORIANS.	RHIZOPODS.	GREGARINIDS.
ACINETARIA.	RADIOLARIA.	
CILIATA.	FORAMINIFERA.	
RHYNCHOFLAGELLATA	LABYRINTHULIDEA.	GREGARINIDA
DINOFLAGELLATA.	HELIOZOA.	or
FLAGELLATA.	LOBOSA.	SPOROZOA.

PROTEOMYXA and MYCETOZOA.
PRIMITIVE FORMS.

Ordinary Functions.—The *Amœba* draws in one part of its cell-substance and protrudes another,—it is *contractile;* it moves apparently "of itself," and shrinks from strong light and obnoxious materials,—it is "*automatic and irritable*"; it makes up for the energy thus expended by eating and digesting food-particles,—it is "*receptive and assimilative*"; within its cell-substance by-products are made, which are retained for further use (*secretions*), or pass out as waste (*excretions*). It is an essential condition of its life, that oxygen be supplied (for life involves an oxidation of the living matter), and that the waste carbon dioxide be got rid of; in other words, the *Amœba respires.* Moreover, when its income exceeds its expenditure, it *grows;* in reverse conditions, or at the limit of growth, it *reproduces.* We have already cited the account of these functions given in the first chapter of the fourth edition of Foster's *Physiology.* There it is also clearly shown how the *Amœba*, discharging all its functions within the compass of a cell, differs from a higher animal in which distinct sets of cells have been specialised for various activities. The Protozoon is structurally or morphologically simple, but in one sense it is, just because of this simplicity, physiologically complex. All the functions are crowded into the activity of a unit mass, whereas a cell in a higher animal has usually one function dominant over the others. It is therefore easier to study the physiology of higher animals, while it is difficult to find out much in regard to the contraction, digestion, and other functions in the Protozoa.

The blunt or thread-like outflowings of Rhizopods are usually associated with streaming movements of the cell-substance, the granules passing inwards and outwards. A somewhat similar streaming may be seen within the cell, both in Protozoa and in some plants. A defined contraction, like that of a muscle-cell, is well illustrated in the stalk of *Vorticella* and some similar Infusorians. The numerous cilia which lash most Infusorians through the water are "bent and straightened alternately," while the flagellum, which is usually a single motile thread, "exhibits lashing movements to and fro, and is thrown into serpentine waves during these movements."

That intra-cellular digestion occurs, that respiration is

aided by the bubbles of water which often enter with the food-particles, that the "contractile vacuoles" help in excretion, are certain facts, though few details are known in regard to these or other functions. In some cases a digestive ferment seems to have been detected, and uric acid is said to occur as a waste-product.

To stimuli such as light, heat, or chemical reagents, the Protozoa respond in a manner which shows considerable sensitiveness, but specially endowed parts, such as pigment-spots, are rare. The Protozoa sometimes behave in a way which suggests conscious effort and intelligence, but as cut-off fragments also act with marvellous reasonableness, and as the nucleus cannot be regarded as a brain, there seems no reason to credit them with more than that diffuse consciousness which is possibly co-extensive with life. Verworn has decided, after much labour, that the Protozoa do not exhibit what even the most sanguine could call intelligence, but this is no reason why he or any other evolutionist should doubt that they have in them the indefinable rudiments of thought.

Structure.—The Protozoa are sometimes called "structureless," but they are only so relatively. For though they have not stomachs, hearts, and kidneys, as Ehrenberg supposed, they are not like drops of white of egg. Our eyes, when aided by the microscope, can distinguish structure in these simplest animals. They are simple as an egg is simple when compared with a bird.

In some cases—probably in all—the cell-substance consists of a living network or foam, in the meshes or vacuoles of which there is looser material. Included with the latter are granules, some of which are food-fragments in process of digestion, or waste-products in process of excretion.

The cell-substance includes a nucleus or several nuclei, essential to the life and multiplication of the unit. There is no need to preserve the term "Monera," applied to very simple Protozoa supposed to be without nuclei, for in some of these the nuclei have been discovered, and it is very probable that nuclear material in some form exists in them all. The nucleus is complex like the cell-substance, for where it is large enough to be well observed, it is seen to consist of a nuclear network, or a coil of nuclear threads. In the division

of many Protozoa, as in the cells of higher animals, the nucleus plays an important part. It passes out of a resting state and becomes active. The nuclear threads or "chromatin filaments" loosen themselves from their coiled state, and arrange themselves in a star at the equator of the cell, whence they divide into two groups, which retreat from one another, and become the daughter nuclei of two daughter cells.

In naked Protozoa, the outer part of the cell-substance ("ectoplasm") is often different from the inner part ("endoplasm"), as one would expect it to be, but this difference is a physical one of little importance. In the other Protozoa, there is a more definite rind or thickened margin of cell-substance. Outside this there may be a "cuticle" distinct from the living matter, sometimes consisting of chitin, or gelatin, or in a few of cellulose. The cuticle may form a cyst, which is either a protection during drought or a sheath within which the unit proceeds to divide into numerous spores. Moreover, the cuticle may become the basis of a shell, formed from foreign particles, or made by the animal itself of lime, flint, or "horny" material.

In the cell-substance, there may be bubbles of water taken in with food-particles (food vacuoles), special pulsating regions which sometimes burst to the exterior like primitive excretory appliances (contractile vacuoles), fibres which seem to be specially contractile (in Gregarines), spicules of flint or threads of horn-like material which may build up a connected framework, pigment of various kinds perhaps including chlorophyll. In the Radiolarians and a few Foraminifera, there are partner plant cells or symbiotic Algæ.

Reproduction of Protozoa.—Growth and reproduction are on a different plane from the other functions. Growth occurs when income exceeds expenditure, when constructive or anabolic processes are in the ascendant. Reproduction occurs at the limit of growth, or sometimes in disadvantageous conditions when disruptive or katabolic processes gain some relative predominance.

As it is by cell-division that all embryos are formed from the egg, and all growth is effected, the beginnings of this process are of much interest. (*a*) Some very simple Protozoa seem to reproduce by what looks like the rupture of outlying

parts of the cell-substance. (*b*) The production of a small bud from a parent cell is not uncommon, and some Rhizopods (*e.g.*, *Arcella*, *Pelomyxa*) give off many buds at once. (*c*) Commoner, however, is the definite and orderly process by which a unit divides into two—ordinary cell-division. (*d*) Finally, if many divisions occur in rapid succession or contemporaneously, and usually within a cyst enclosing the parent cell, *i.e.*, in narrowly limited time and space, the result is the formation of a considerable number of small units or spores. Rupture, budding, division, and multiple division or spore-formation are the methods by which the Protozoa multiply. In the great majority of cases each result of division is seen to include part of the parent nucleus.

A many-celled animal multiplies in most cases by liberating reproductive cells—ova and spermatozoa—different from those which make up the "body." A Protozoon multiplies by dividing wholly into daughter cells. This difference between Metazoa and Protozoa in their modes of multiplication is a consequence of the difference between multicellular and unicellular life. Each part of a divided Protozoon is able to live on, and will itself divide after a time, whereas the liberated spermatozoa and ova of a higher animal die unless they unite.

By sexual reproduction, we usually mean (*a*) the liberation of special reproductive cells from a "body," and (*b*) the fertilisation of ova by spermatozoa. It is obvious that unicellular Protozoa can show nothing corresponding to sexual reproduction in the first sense. Moreover, Protozoa can live on, dividing and multiplying, for prolonged periods without the occurrence of anything like fertilisation.

So it is often stated as a characteristic of Protozoa that "they have no sexual reproduction." But if this means that the Protozoa have no special reproductive cells, then it is a truism. As unicellular animals, they can have neither ova nor organs. If, however, the statement mean that the Protozoa are without anything corresponding to fertilisation, then it is not true. For in the majority of Protozoa, there occurs at intervals a process of "conjugation" in which two individuals unite either permanently or temporarily. This

is an incipiently sexual process; it is the analogue of the fertilisation of an ovum by a spermatozoon.

It is one of the recurrent phases in the life-history of some of the simplest Protozoa (Proteomyxa and Mycetozoa, see p. 108), that a number of amœboid units flow together into a composite mass, which has been called a "*plasmodium.*"

It is known that more than two individual Gregarines and other forms occasionally unite. To this the term "multiple-conjugation" has been applied.

Commonest, however, is the union of two apparently similar individuals, either permanently so that the two fuse into one, or temporarily so that an exchange of material is effected. Permanent conjugation has been observed in several Rhizopods, Infusorians, and Gregarines. Temporary conjugation is well known in not a few ciliated Infusorians, and it is possible that a curious end-to-end union established between certain Gregarines is of the same nature.

Fourthly, there are some cases where one of the conjugating individuals is larger and less active than the other. Thus in *Vorticella*, a small free-swimming form unites and fuses completely with a stalked individual of normal size. To call this "dimorphic conjugation" is hardly necessary, since it is evidently equivalent to the fertilisation of a passive ovum by an active spermatozoon, one of the well-known characteristics of reproduction in the Metazoa.

The conjugation of ciliated Infusorians, such as *Paramœcium*, has been studied with great care by Gruber, Maupas, R. Hertwig, and others, and though their results are not quite harmonious, the main facts are secure. In the ciliated Infusorians there are two nuclear bodies, one large, the other small. The smaller or micro-nucleus lies by the side of the larger or macro-nucleus. The micro-nucleus divides into parts, while the macro-nucleus degenerates. Two individual Infusorians (A and B) lie side by side in close contact, and a portion of the micro-nucleus of A passes into B, and a portion of the micro-nucleus of B passes into A, or else two portions of A and B simply come into very close contact. An interchange of some sort takes place, the conjugating individuals separate, a new micro-nucleus and a new macro-nucleus are established in each.

That there is in these cases a mutual fertilisation of some sort we cannot doubt. But the precise interpretation of the process is to some extent a matter of mere opinion. We may regard it as a mutual rejuvenescence, each unit supplying some substances or qualities which the other lacks ; or we may regard it rather as a process by which the average character of the species is sustained, peculiarities or pathological variations of one individual being counteracted by other characters in the neighbour (apparently no near relation) with which it conjugates. But the researches of M. Maupas have thrown considerable light on the facts, and some of his results I shall now summarise.

It has been often alleged that the subsequent dividing is accelerated by conjugation; but Maupas finds that this is by no means the case. The reverse in fact is true. While a pair of Infusorians (*Onychodromus grandis*) were engaged in conjugation, a single individual had, by ordinary asexual division, given rise to a family of from forty thousand to fifty thousand individuals. Moreover, the intense internal change preparatory to fertilisation, and the general inertia during subsequent reconstruction, not only involve loss of time, but expose the Infusorians to great risk. Conjugation seems to involve danger and death rather than to conduce to multiplication and birth.

The riddle was, in part at least, solved by a long series of careful observations. In November 1885, M. Maupas isolated an infusorian (*Stylonichia pustulata*) and observed its generations till March 1886. By that time there had been two hundred and fifteen generations produced by ordinary division, and since these lowly organisms do not conjugate with near relatives, there had, of course, been no sexual union.

What was the result ? At the date referred to, the family was observed to have exhausted itself. The members were being born old and debilitated. The asexual division came to a standstill, and the powers of nutrition were lost.

Meanwhile, before the generations had exhausted themselves, several of the individuals had been restored to their natural conditions, where they conjugated with unrelated forms of the same species. One of these was again isolated,

and watched for five months. The usual number of successive generations occurred. On to the one hundred and thirtieth generation, members were removed at different stages, and were observed to conjugate successfully with unrelated forms. But when the family began to draw near its end, even removal to fresh conditions was without effect. About the one hundred and eightieth generation, the strange sight was seen of individuals of the same family attempting to unite with one another. The results were, however, *nil*, and the conjugates did not even recover from the effects of their forlorn hope.

Without the normal sexual union, then, the family becomes senile. Powers of nutrition, division, and conjugation with unrelated forms, come to a standstill. This senile degeneration is very interesting. The first symptom is decrease in size, which may go on till the individuals only measure a quarter of their normal proportions. Various internal structures then degenerate, "until at last we see formless abortions, incapable of living and reproducing themselves." The nuclear changes are no less momentous. The more important micro-nucleus may partially or completely atrophy, and conjugation is therefore sterile. The larger nucleus may also become affected; "the chromatin gradually disappearing." Physiologically, too, the organisms become manifestly weaker, though there is what M. Maupas calls a "surexcitation sexuelle." Such senile decay of the individuals and of the isolated family inevitably ends in death.

The general conclusion is evident. Sexual union in those infusorians, dangerous perhaps for the individual life, and a loss of time so far as immediate multiplication is concerned, is absolutely necessary for the species. The life runs in cycles of asexual division, which are strictly limited. Conjugation with unrelated forms must occur, else the whole life ebbs. Without it, the Protozoa, which some have called "immortal," die a natural death. Conjugation is the necessary condition of their eternal youth

DIAGRAM IV.

THE CLASSES OF PROTOZOA.

In the lowest line the life-cycle of *Protomyxa* is represented. The median figure (*pl.*) is a plasmodium; to the right is the encysted phase (*enc.*), within which the protoplasm divides into many units or spores (*sp.*). To the left the cyst bursts, liberating flagellate spores (*fl.*), which sink down into amœboid units (*am.*), from the coalescence of which a plasmodium results. The phases of this life-cycle furnish the key to the whole classification.

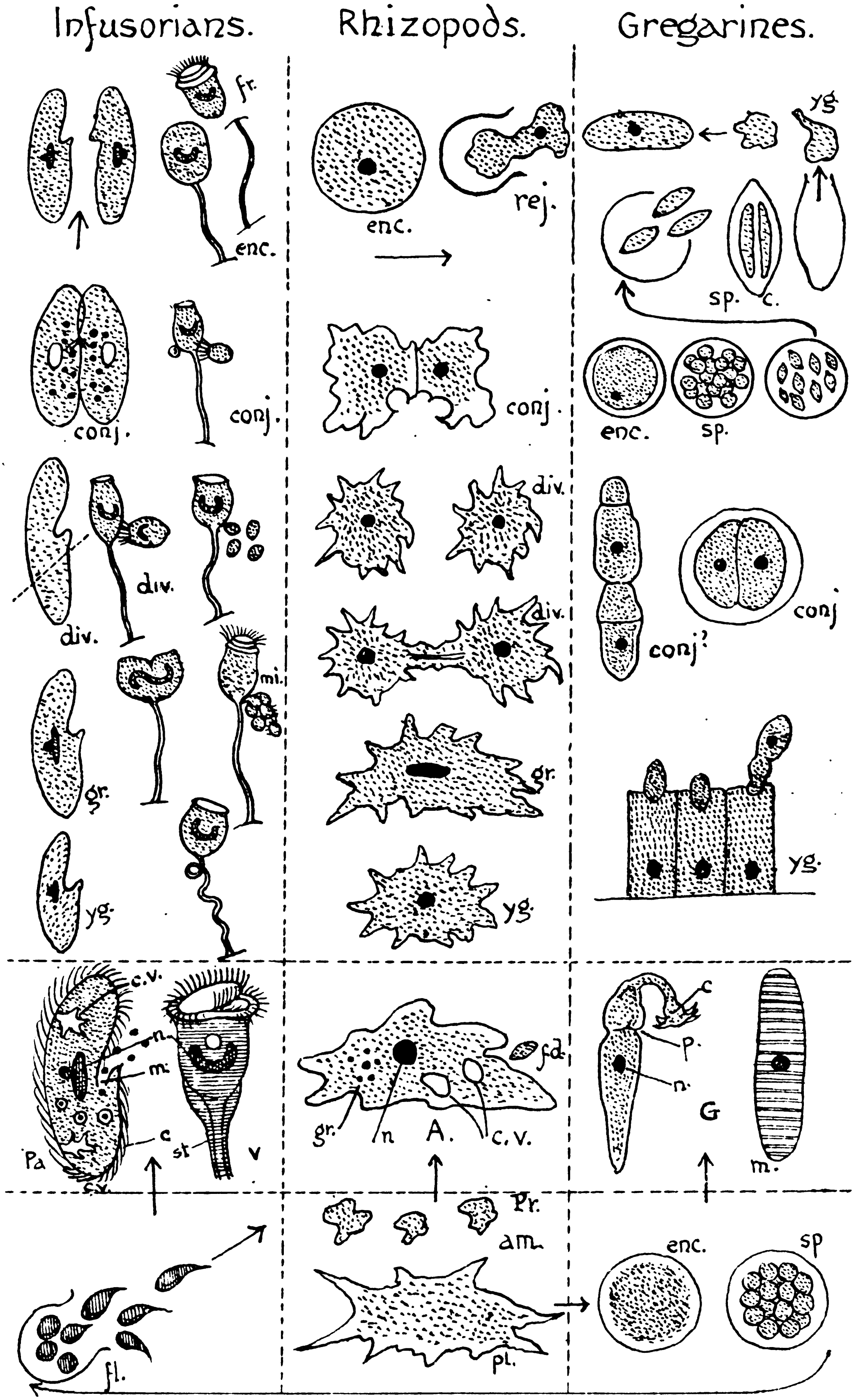
In the next line are examples of the three great divisions. In the middle, is an *Amœba* (*A.*), with nucleus (*n.*), granules (*g.*), contractile vacuoles (*c. v.*); it is about to engulf a small particle of food (*fd.*). To the right side, is a Gregarine with its substance divided by a partition (*p.*), with a caducous cap (*c.*) at the anterior end. The next figure (*m.*) to the right is another Gregarinid, without a partition, but with numerous transverse fibrils. To the left side, is the cup of *Vorticella* (*v.*), showing the anterior cilia, the curved nucleus (*n.*), the beginning of the stalk (*st.*) with its central axis. Further to the left is *Paramœcium*, with macro-nucleus (*n.*) and micro-nucleus beside it, with mouth (*m.*) and food-particles entering, with contractile vacuoles (*c. v.*), with food-vacuoles round the nutritive particles, with cilia (*c*) on the surface.

Follow the median division upwards. The young *Amœba* (*yg.*) grows larger (*gr.*), divides into two (*div.*). Conjugation (*conj.*) has been observed. Encystation occurs (*enc.*), and rejuvenescence (*rej.*) when the cell escapes from its cyst.

Follow the history of a Gregarine. The young forms (*yg.*) are usually intra-cellular parasites. Sometimes individuals unite in a strange end-to-end fashion (*conj.* ?); sometimes two fuse and encyst (*conj.*). Within the cyst (*enc.*) spores are formed (*sp.*), one or more in each of the many spore-cases (*sp. c.*). The cyst bursts, the spore-cases open, the young forms (*yg.*) may be slightly amœboid, as the topmost line suggests.

Follow the history of *Vorticella*. It divides longitudinally (*div.*), and the halves separate; or one-half may divide into 8 minute units (*mi.*). A small individual conjugates with one of normal size (*conj.*). Encystation (*enc.*) may occur, and the cup may free itself from its stalk (*fr.*).

The young *Paramœcium* (*yg.*) grows (*gr.*) and divides (*div.*). In conjugation (*conj.*) the micro-nucleus divides into 8, the macro-nucleus (left light in this figure) degenerates. After conjugation and subsequent separation (topmost figure) the nuclei are reconstructed.



Infusorians.
Rhizopods.
Gregarines.
fr.
enc.
rej.
yg.
sp.
c.
conj.
enc.
sp.
div.
conj?
conj
mi.
gr.
yg.
c.v.
n.
m.
c
st
Pa
V
fd.
gr.
n
A.
c.v.
p.
G
m.
Pr.
am.
pl.
fl.
sp

SPECIAL TYPES.

Amœba—a type of Rhizopods, especially of those in which the outflowing processes of living matter are blunt and finger-like (Lobosa).

Description.—*Amœba proteus* and some other species are found on the muddy bottom of ponds ; *A. terricola* occurs in damp earth. Some are just large enough to be seen with the unaided eye. They glide along the surface of stone or plant by protruding and retracting blunt processes, and their changefulness merits the old (1755) popular name of "Proteus animalcule." The food, which consists of minute Algæ such as diatoms, or of vegetable débris, is surrounded by the finger-like processes, and engulfed along with drops of water, which form food vacuoles in the cell-substance. Round the margin, which sometimes shows an apparent radial striation, the cell-substance is firmer and clearer than in the interior, where granules and débris often obscure the normal clearness. A single nucleus lies in the centre of the cell. Indigestible débris and waste particles are got rid of, by being left behind in the onward flowing of the animal, and two contractile vacuoles seem to aid in the excretion of the finer waste-products.

Life-History. — In favourable nutritive conditions, the *Amœba* grows. At the limit of growth it reproduces by dividing into two. In disadvantageous conditions, such as drought, it may become encysted and lie dormant for a while. The return of prosperity revives it, and it bursts with renewed energy from the cyst. The permanent conjugation of two *Amœbæ* has been observed, and it is said that a mode of spore-formation occasionally occurs.

Paramœcium—a type of Infusorians, especially of those which are uniformly ciliated.

Description.—Specimens of *Paramœcium* may be readily and abundantly obtained, by leaving fragments of hay to soak for a few days in a glass of water. A few Infusorians have been lying dormant about the plant, they revive and multiply with extraordinary rapidity. They are abundant in most stagnant pools, and are just visible when a test tube

containing some of them is held between the eye and the light. Their food consists of small vegetable particles.

In form, *Paramœcium* is a long oval; the cell-substance is bounded by a definite rind; the cilia, which occur all over in regular rows, serve for locomotion and for driving food-particles into an opening or "mouth" on one side. Among the cilia on the rind, there are small cavities in which lie fine protrusible threads ("trichocysts"), believed to be of the nature of weapons. Internally, there are two nuclei, the smaller "micro-nucleus" lying by the side of the larger "macro-nucleus." There are food vacuoles as usual, and two contractile vacuoles drain the surrounding cell-substance and burst to the exterior.

Life-History.—Growth is followed as usual by division into two. One-half includes the "mouth," the other has to make one. In conjugation, which is essential to the continued fitness of the species, two individuals interchange certain micro-nuclear elements, and both nuclei are entirely reconstituted.

Vorticella or the bell-animalcule,—a type of those ciliated Infusorians in which the cilia are restricted to a region around the mouth.

Groups of *Vorticella* grow on the stems of freshwater plants, and are readily visible to the unaided eye as white fringes. Each individual suggests a bell with a long flexible handle. The base of the stalk is moored to the water-weed, the bell swings in the water, now jerking out to the full length of its tether, and again cowering down with the stalk contracted into a close and delicate spiral. Up the centre of the stalk runs a contractile filament, which in shortening gives the non-contractile sheath a spiral form. The "mouth" is at one side of the upper margin of the bell, and the cilia round about this margin and close to the mouth, are arranged in a manner which secures the inwafting of food-particles. The nucleus is of horse-shoe shape. Food vacuoles and contractile vacuoles are present as usual.

Sometimes a *Vorticella* bell jerks itself off its stalk and swims about; in other conditions it may be passive and somewhat encysted; normally the cilia of the bell are very active, and the contractions and expansions of the stalk

frequent. The bell often divides into almost similar halves, one of which may go free. Or one of the halves still attached to the stalk may rapidly divide into eight small individuals, which are then set adrift. Each of these, having a posterior circlet of cilia, swims actively, and may conjugate with a stalked individual of normal size. In this case, very different from the conjugation of *Paramœcium*, the small individual (like a spermatozoon) fuses wholly and intimately with the other, which in its larger size and passivity may be likened to an ovum.

Gregarina—a type of those Gregarinida or Sporozoa, in which the cell is divided into two regions by a partition.

Various species of *Gregarina* occur in the intestine of lobster, cockroach, and other Arthropods, as cellular parasites when young, free within the gut when adult. They absorb diffusible food-stuffs from their hosts. The maximum size is about one-tenth of an inch. There is a firm cuticle, and delicate fibrils sometimes extend across the cell-substance, producing an appearance a little like that of striated muscle. The unit is divided into a larger nucleated posterior region, and a smaller anterior region, and at the apex there is usually a small dead cap, which is lost after the attainment of free intestinal life. Underneath the cuticle lies a definite cortical stratum of the cell-substance, within which the contents are more fluid; the nucleus is very distinct, but there are no vacuoles. We may associate the absence of locomotor processes, "mouth," and contractile vacuoles, as well as the thickness of the cuticle and the general passivity, with the parasitic habit of the Gregarines.

Let us begin with a young form parasitic in one of the lining cells of the gut; it grows and emerges till it hangs attached to the cell by its cap only; it becomes free and still increases in size. Two individuals often attach themselves end to end, but the meaning of this is obscure. Encystation occurs involving a single unit or two together, and from the division of the encysted cell spores are formed. The cyst is sometimes (as in *G. blattarum*) complex, with "ducts" serving for the exit of the spores, each of which is surrounded by a firm case. Eventually the cyst bursts, the spore-cases are liberated, and from within each of these the spore

emerges and becomes a cellular parasite. The spore of *G. gigantea*, the species inhabiting the lobster's intestine, is non-nucleated and somewhat globular. It forms two processes, of which one remains short and motionless, while the other growing long and vibratile, becomes nucleated, and is detached. The other part seems to come to nothing.

Monocystis—a type of those Gregarinida or Sporozoa in which the cell is not divided into two parts by a partition.

Two species of *Monocystis* (*M. agilis* and *M. magna*) infest the male reproductive organs of the earthworm so constantly, that we are almost always sure of finding them. The full-grown adults are visible to the naked eye. They are somewhat cylindrical cells, but change their form as they sluggishly move. There is a definite contractile cortex, and a large nucleus in the central substance.

Let us begin with a young form parasitic within one of the reproductive cells of the earthworm. It grows and becomes free from the cell. In some species, the curious end-to-end adhesion of two individuals has been observed. Encystation occurs, involving a single individual or two together. Within the cyst, orderly nuclear division results in the formation of spore-forming masses. These form elliptical spore-cases or "pseudonavicellæ," enclosed in a firm sheath. Each spore-case contains several, usually eight spores, lying around a residual core. The cyst bursts, the spore-cases are extruded, the spores emerge from the firm cases. The young spore is more active than the adult; indeed, in some Gregarines it is for a brief period flagellate, then amœboid, then like the sluggish adult. Intra-cellular parasitism and copious food naturally act as checks to activity.

SYSTEMATIC SURVEY OF PROTOZOA.

Most Protozoa are unicellular animals.

A.—Primitive Forms.

1. PROTEOMYXA.—A class established by Ray Lankester, and described by him as "a lumber-room in which obscure, lowly-developed, and insufficiently known forms may be kept until they can be otherwise

dealt with." They are simple in structure, often parasitic in habit, and protean in their phases. In some, no central body or nucleus has yet been detected. They occur in fresh water, in the sea, and parasitically.

Examples.—Protomyxa, in four phases :—(1) encysted and breaking up into spores, which (2) are briefly active, (3) sink into amœboid forms, (4) flow together into a composite "plasmodium." *Vampyrella*, parasitic on fresh-water Algæ. *Protogenes*, the simplest "amœba." *Protobathybius*, dredged up in masses from the depths. *Schizogenes*, multiplying by mere breakage. *Archerina*, with chlorophyll, like a sun-animalcule (Heliozoon). *Monobia*, dividing into beautiful colonies, illustrating "sociality" at a low level.

2. MYCETOZOA.—Protozoa which live on land and have a fungus-like habit of feeding on decaying vegetable matter. The plasmodial stage in the cycle is predominant. From encysted plasmodia, or parts of them often elaborate in structure, coated spores are produced; the spores may have a brief flagellate activity and sink down into amœboid forms, or become at once little amœbæ; the amœbæ grow and consequently multiply, and after a while collect into the characteristic fused masses or plasmodia.

Example.—Fuligo or *Æthalium septicum*, "flowers of tan"—a large spreading mass found in summer on the bark of the tan yard. This and the other forms are sometimes ranked as plant organisms, but De Bary, whose opinion is authoritative, has given good reasons for keeping them among the Protozoa. It is of course natural that some of these primitive forms should appear to hesitate between the two paths.

B.—Predominantly Amœboid Protozoa—Rhizopoda.

3. LOBOSA, in which the living matter flows out and in as protean, usually blunt, never interlaced processes. A physical difference between outer and inner portions, one nucleus or more, bubbles of water engulfed along with the food, special pulsating regions, and granules, may generally be observed. They multiply in most cases by dividing into two, but in some cases liberate numerous buds (*Arcella*), or may rarely form spores (*Pelomyxa*). They sweat off a protecting cyst in unfavourable conditions. Two individuals may unite in congugation. Most of them occur in fresh water, some in the sea, a few are parasitic.

Examples.—(*a*) Naked forms :—*Amœba*, and the giant amœba *Pelomyxa*; (*b*) Shelled forms:—*Arcella*, with a firm (chitinoid) shell; secreting gas bubbles which float it; and *Difflugia*, shut in except at one end by a membrane, with foreign bodies such as sand grains glued over it. *Magosphæra* (Catallacta), a unique form described by Hæckel—(*a*) in an encysted phase; (*b*) as a free-swimming colony of ciliated cells (like the embryo of some sponges); (*c*) as ciliated units produced from the breaking up of (*b*); (*d*) as amœboid forms resulting from modifications of the active units.

4. *Labyrinthulidea*, compound forms consisting of a mass of protoplasm spreading out into a network, and of numerous spindle-shaped units which travel continually up and down the threads of the living net.

Examples.—Labyrinthula (on Algæ), *Chlamydomyxa* (on bog-moss).

5. HELIOZOA, with stiff processes radiating from a spherical body. The outer protoplasm has usually larger vacuoles than the internal portion; there may be numerous nuclei, and one or more contractile vacuoles. There may be loose flinty needles (*Raphidiophrys*); or rarely a connected framework (*Clathrulina*); or a jelly-like envelope (*Heterophrys*); or nothing of the kind (*Actinosphærium*). Multiplication by division or by spores. Conjugation occurs. Encystation and spore-making, and in some young forms flagellate phases are known; the stiff processes become more amœboid in food-catching. Compared with Lobosa, the Heliozoa are passive. The majority occur in fresh water.

Examples.—*Actinosphærium*, *Actinophrys sol* (sun-animalcules); *Raphidiophrys*, forming colonies; *Clathrulina*, stalked.

6. FORAMINIFERA.—Predominantly amœboid forms, with fine branching and interlacing processes issuing from the main mass, which is always within a shell usually calcareous. A nucleus is present, but often multiplies, apparently in association with reproduction. Vacuoles, contractile or otherwise, seem to be very rare. Conjugation has not been certainly observed. Multiplication may take place by division, but usually by the repeated division of the nucleus and the formation of internal bud-spores. The great majority are marine, occurring at all depths. Those from the depths have usually shells of glued sand; the limy forms are found at their best in the shallow water of warm seas, but some occur in the open sea, and sink down as they die to form ooze. They are common as fossils from Silurian strata onwards.

Examples.—*Gromia*, often in fresh water, with a single opening to its shell; *Microgromia socialis*, in fresh water, forming colonies; *Shepheardella*, with an opening at each end of a long membranous case; *Miliolina*, with a chambered shell simply coiled, and a single aperture; *Lagena*, with a simple flask-shaped shell, with diffuse holes for the processes; *Globigerina*, a pelagic limy form, with many chambers covered with pores, contributes very largely to the ooze; *Hastigerina*, apparently thriving at great depths, with bubbly protoplasm abundantly overflowing round the shell, which comes to be internal like a Radiolarian "central capsule" (q.v.); *Ammodiscus*, from the depths, with flinty glued shell; *Haliphysema*, a form utilising sponge spicules to cover itself, once mistaken for a minute sponge or for a very simple many-celled animal.

Most kinds of chalk consist mainly of the shells of Foraminifera, accumulated on the floor of ancient seas; *Nummulites* and related fossil forms were as large as shillings or half-crowns; *Eozoon*, once regarded as a fossil (from pre-Cambrian strata), is more plausibly inorganic. As regards shells and historic sequence, Foraminifera may be grouped in three grades—(*a*) with irregularly glued shells; (*b*) with regularly glued shells; (*c*) with limy shells.

7. RADIOLARIA.—"Marine Rhizopods, whose unicellular body always consists of two main portions separated by a membrane,—an inner central capsule (with one or more nuclei), and an outer portion, giving off radiating threadlike processes. The protoplasm of the two regions is connected by openings in the capsule membrane. The central capsule is partly the general central 'organ' of the Radiolarian cell, partly the special 'organ' of reproduction, since its protoplasm, along with the

nuclei embedded in it, serves for the formation of flagellate spores. The extra-capsular portion is partly the general 'organ' for intercourse with the outer world, partly the special 'organ' of protection and nutrition. The skeleton (usually present) varies in form, and is generally composed of silica arranged in one of sixteen or twenty geometrical forms, sometimes of a horn-like substance called acanthin. The cell usually leads an isolated existence (*Monocyttaria*); only a few form colonies of cells (*Polycyttaria*)." (With a few verbal changes, from Hæckel's "*Challenger*" *Report, 1887.*)

Most Radiolarians include unicellular plants, with which they live in intimate mutual partnership (symbiosis). Division is probably the commonest mode of multiplication, but flagellate spores—sometimes of two sizes, small and large, as if male and female—have also been observed. Their conjugation is still unknown. Lankester notes that the central capsule of a Radiolarian may be compared with the buried shell of *Hastigerina*, and that the character of the protoplasm, which in contrast with that of Foraminifera is abundantly vacuolated, may be associated with the pelagic life, which is rare in the former class. Radiolarians form much of the ooze of the great depths, and occur abundantly as fossils from Palæozoic times.

The general classification is based on the chemical nature of the skeleton (flint or acanthin), and on the nature of the openings in the central capsule.

Examples.—*Thalassicola* (no skeleton); *Acanthometra* (acanthin); *Actinomma* (flinty skeleton, central capsule with pores all over); *Eucyrtidium* (flinty skeleton, with one perforate area in cone-shaped central capsule); *Aulosphæra* (flinty skeleton, central capsule with more than one perforate area); *Collozoum* and *Sphærozoum*, multicellular colonial forms.

C.—Predominantly Encysted Forms.

8. GREGARINIDA (or better, perhaps, SPOROZOA). — Protozoa of parasitic habit, very passive in adult life, clothed by a definite rind, almost never with any locomotor processes. Found in almost all kinds of animals; often, especially when young, within the cells of their host; deriving their food by absorbing diffusible juices. A single large nucleus; no contractile vacuole. Reproduction by division in early life, but typically by spore-formation. An encysted phase precedes the division into encased spores. The young forms escaping from a spore-case may be flagellate or amœboid; but, except in a very few cases, passivity prevails, and the adults are much restricted in their contractile movements. Conjugation, followed by fusion, often precedes encystation; and independently of the latter two forms often occur associated but not fused.

Examples.—*Monocystis*, in earthworm; *Gregarina*, with a cross partition, in food-canal of Arthropods; *Eimeria*, remaining, except in young stages, within a cell of the host; *Drepanidium*, and other forms, in blood corpuscles; *Myxidium*, with amœboid adult; *Sarcocystis*, in muscle fibres of Mammals and some other Vertebrates.

D.—*Predominantly Active Forms (ciliate and flagellate), generally called Infusorians.*

(*Occurring in fresh or sea water, abundant in infusions.*)

9. FLAGELLATA, units with a definite rind, with one or a few actively undulating locomotor processes (flagella), often with a distinct aperture for the entrance of food. Reproduction by division into two, or by multiple division within a cyst. Conjugation and encystation are common. Some forms are colonial, and suggest the transition to Metazoa.

Examples.—*Mastigamœba*, possessing a flagellum and amœboid processes; *Euglena*, with green or variable colouring matter, probably feeding for the most part like a plant; *Volvox*, also green, forming colonies, which illustrate the beginning of sex; *Codosiga*, with stalked colonies, each individual with a collar around the base of the flagellum; *Proterospongia*, colonial, like a detached piece of sponge.

10. DINOFLAGELLATA, very successful Protozoa, which combine activity and passivity, having two flagella and generally a cellulose coat. The one flagellum projects from a longitudinal groove, the other lies in a transverse groove. Mostly marine.

Examples.—*Peridinium* and *Ceratium*.

11. RHYNCHOFLAGELLATA, large forms, with firm skin and very spongy protoplasm, with two flagella, the larger one striated like a muscle, springing from a deep groove, the smaller one near the aperture for the food.

Examples.—The phosphorescent *Noctiluca*; *Leptodiscus medusoides*, disc-like in form, swimming like a miniature medusoid.

12. CILIATA, provided with numerous bending-processes or cilia, which drive the animals swiftly, and waft food-particles into the "mouth." There is a definite rind. Beside the large macro-nucleus there always lies a micro-nucleus or "para-nucleus." There are usually two contractile vacuoles. Multiplication by rapidly succeeding divisions; in rare cases spores seem to be formed. Conjugation (essential to the vitality of the species) has in some cases at least been shown to be associated with intimate interchange of para-nuclear material. Parasitic forms, some mouthless, are not uncommon.

Examples.—(*a*) Peritricha, with a circle of cilia at one end or at both, *e.g.*, *Vorticella*. (*b*) Heterotricha, with long and short cilia, *e.g.*, *Stentor*; *Balantidium coli*, in intestine of man. (*c*) Holotricha, uniformly ciliated, *e.g.*, *Paramœcium*; *Opalina*, in intestine of frog, with numerous nuclei, and no contractile vacuoles. (*d*) Hypotricha, locomotor cilia confined to under surface, *e.g.*, *Stylonichia*.

13. ACINETARIA, ciliated when young, and probably derived from the Ciliata, but more passive when adult. They are fixed in adult life, generally stalked, and bear tentacle-like processes often suctorial. The nucleus is sometimes branched. They have one or more contractile vacuoles. They multiply by division, or by the formation of buds which usually remain for a time partly enclosed by the parent. Their food consists of other Protozoa. They represent "an extreme modification

of the Protozoon series, in which the differentiation of parts in a unicellular animal reaches its highest point" (Lankester).

Examples. — *Acineta*, suctorial; *Dendrosoma*, forming branched colonies, suctorial; *Ophryodendron*, non-suctorial.

General Interest of Protozoa.

The Protozoa illustrate, in free and single life, forms and functions like those of the cells which compose the many-celled animals.

They remain at the level represented by the reproductive cells of higher forms, and are comparable to reproductive cells which have not formed bodies. They are self-recuperative, and in normal conditions they are not so liable to "natural death" as are many-celled animals. Weismann and others maintain that they are physically immortal.

They illustrate (*a*) the beginnings of reproduction, from mere breakage to definite division, either into two, or in limited time and space into many units; (*b*) the beginnings of fertilisation, from "the flowing together of exhausted cells" and multiple conjugation to the specialised sexual union of some Infusorians; (*c*) the beginnings of sex, in the difference of size sometimes observed between two conjugating units; (*d*) the beginnings of many-celled animals, in the associated groups or colonies which occur in several of the Protozoon classes.

Lastly, in their antitheses of passivity and activity, constructive preponderance and destructive preponderance, anabolism and katabolism, they furnish a key to the variation of higher animals.

CHAPTER IX.

PORIFERA OR SPONGES.

We begin the series of many-celled animals with Sponges, because their average structure is simpler than that of any other class. A sponge compares with sea-anemone or worm, very much as a primitive community compares with a city. For a sponge is a community of cells among which there is little division of labour and little unified life; in technical language, it is an aggregate imperfectly integrated. With the exception of the fresh-water *Spongilla*, the sponges live in the sea,—on rocks, shells, seaweed, and the like.

Take one of the simplest. It has the form of a cup, and is moored to a rock in the sea. Its cells are arranged in three strata, a thin outer skin (ectoderm), a lining of active ciliated cells (endoderm) round the cavity of the cup, and between these two a middle stratum (mesoglœa), among the cells of which lie numerous needles of lime. Put a pinch of powdered carmine into the water, and you will see in part how the sponge lives. For the particles are drawn in through minute pores all over the surface of the sponge, they pass into the cavity of the cup, and they are driven out again in a stream from the large upper aperture. To what are the currents due? Obviously to the lashing activity of the ciliated cells. The community is Venice-like, penetrated by canals. By these, food and other necessaries are continually supplied to the houses or cells by the banks; and a constant current is sustained by the life of the city.

But while this is a true sketch of more than one sponge, it will not apply to all. The sponge of commerce, for instance, with whose "horny" skeleton we are so familiar, is much more intricate. Indeed, there are many very complex

sponges whose ground plan and waterways are hard to trace. Yet it is not difficult to gain some idea of their origin. With the simple primitive cups, the complex forms are connected by a gradual series of steps, and simple cups they all are when very young.

Several facts help us to understand how the complications arise. The older naturalists called sponges plants, and there is certainly much of the character of plants about them. They are sedentary and passive, and seem to feed easily and well by drawing in water and food-particles, as we have described. It is natural, therefore, that they should bud or branch as plants often do. But these buds, like the suckers round a rose-bush, often acquire some apparent independence, and the sponge looks like many cups, not like one. Moreover, as they grow, the buds may join together and fuse like branches of a tree tied closely together. Thus the structure becomes intricate, while it must also be noted that, just as trees may be blown out of shape by the wind, or may grow of themselves into various forms, so the sponges are carved by currents, moulded by the substratum on which they grow, or influenced by peculiarities of their own constitution. Again, in the simple cup the internal cavity is continuously lined by characteristically collared ciliated cells, while in the more complex forms these are restricted to numerous little chambers, communicating on the one hand with incurrent, on the other hand with excurrent canals. How do these arise? As the cup grows, the inner layer increases more rapidly than the outer, and becomes folded into a series of radial chambers; these retain the characteristic ciliated cells, while the lining of the central cavity into which they all open loses them. But each of the radial chambers grows in a similar way; each is folded into a series of side aisles which retain the collared ciliated cells, while the cavity of the radial chamber becomes a mere canal. This process of folding is continued, and the common condition with numerous separate ciliated chambers results.

Again, in the simple cup the middle stratum is a very simple structure; always, indeed, it seems to owe its units to contributions from the inner layer. In more complex forms it acquires more prominence, and its cells become more numerous and varied. Some make spicules of lime, or flint,

or threads of sponge-stuff; others become muscle-cells, which may be able to close the large exit pores; others may contain pigment, for the sponges are often brightly coloured; others become irregular binding cells, the beginning of what is called connective tissue. Morever, some well-fed cells of this mesoglœa become ova, and others divide into balls of spermatozoa.

To avoid complications, we have not spoken of the cells lining the canals which lead to and from the chambers with collared ciliated cells. It seems that at least the more external regions of the afferent canals are lined by an in-turning of the flat ectoderm cells, while the efferent canals at any rate are endodermic. On these canals flat ciliated cells occur, but they are very different from the monad-like collared cells of the ciliated chambers.

If you realise the effect of the budding and the fusion of buds, the folding of the inner layer and the restriction of the cilia to small chambers, the complication of the middle stratum and the framework it builds, you will understand how a complex sponge is derived from a simple cup.

Kinds of Sponges—Perhaps the most convenient general classification of sponges is that which distinguishes three main sets :—

(1) Calcareous (Calcispongiæ), with spicules of carbonate of lime;

(2) Siliceous (Silicispongiæ), with spicules and threads of silica;

(3) Horny (Ceratospongiæ), with a framework of somewhat horny material.

To these may be added a few forms which have no skeleton (Myxospongiæ).

(1.) *Calcispongiæ.*—The calcareous sponges have a world-wide distribution in the sea, from between tide marks to depths of 300–400 fathoms. The simplest (Ascones) are simple cups such as we have described, and lead by a gradual series of forms through Sycones, to a height of complexity in Leucones. The purse-like *Sycandra* (or *Grantia*) *compressa*, is common on British shores.

(2) *Silicispongiæ.*—The siliceous sponges are more numerous, diverse, and complicated. Very familiar is the marvellously beautiful skeleton of *Euplectella*—the Venus' flower-basket—a type of those whose (Hexactinellid) spicules have six rays lying in three axes. Like the glass-rope sponge (*Hyalonema*) and others, it lives anchored in the mud of the deep sea. But let us rather mention a few of the commonest flinty

sponges of Britain. Mermaid's gloves, or *Chalina oculata*, is a large branched form, with spicules mostly needle-like, and with a fibrous skeleton as well. The "crumb of bread sponge," or *Halichondria panicea*, grows on the rocks as a slightly greenish crust, broken at intervals by crater-like exhalent apertures, with crowded needle-like spicules, but without any fibrous skeleton; it crumbles readily in our hands. On the shore you often find oyster shells riddled with holes, as if they had been bored all over with a gimlet; these holes were tenanted by a small yellowish burrowing sponge, *Clione*, which by some chemical action eats into shells, and even into limestone rocks. Sometimes washed ashore is the not less interesting *Suberites domuncula*, a compact orange-coloured sponge of peculiar odour, which grows round a buckie-shell tenanted by a hermit-crab, and thus gets carried about from place to place—an unusual privilege for a sponge. But *Suberites* eats into the shell of the buckie, and the hermit-crab doubtless leaves its quarters. Unique in habitat are the fresh-water sponges (*Spongilla*) common in some rivers, canals, and lakes, notable for their plant-like greenness, and for a curious life-history which we shall afterwards relate.

These flinty sponges are classified in part according to the spicules, as their rays lie in one axis (Monaxonia), or in three (Triaxonia), or in four (Tetraxonia), and F. E. Schulze has shown how each of these three types of spicule is suited to, and indeed depends upon the soft structure of the sponge in which it prevails.

(3) *Ceratospongiæ.*—The so-called horny sponges, which have a framework of spongin or sponge-stuff and no proper spicules, are well represented by the bath sponges (*Euspongia*), which thrive at many places off the Mediterranean coasts.

Life of Sponges.—The motor activity of a sponge is almost restricted to the internal cilia. Sensitiveness to surrounding influences is shown by the closure of the little pores, and sometimes even of the large exhalent aperture. This is effected by special muscle-cells in the mesoglœa, which are probably stimulated by sensitive and nervous cells on the surface. The food carried down the canals consists of microscopic organisms and particles of organic débris; these are caught as they pass by the ciliated cells, which behave like so many monads, swallowing first, digesting intra-cellularly afterwards. From these cells which feed, surplus material oozes to their neighbours, or is passed to wandering amœboid cells in the middle stratum. Useless débris is rapidly got rid of also by the collared cells. Some of the bright pigments, such as floridine, readily absorb oxygen, and therefore help in respiration, while the green of the fresh-water sponge is at least closely analogous to chlorophyll.

Sponges spread like plants by overgrowth or budding, and

small portions are sometimes set adrift from a sickly parent mass. Moreover, for commercial purposes, the bath sponge is cut in pieces and bedded out, the fragments reproducing the whole as do cuttings from many plants. The life-history of *Spongilla*, as told by Marshall, is one of interesting vicissitudes. In autumn, the sponge begins to suffer from the cold and the scarcity of food, and dies away. But throughout the moribund parent, clumps of cells combine into "gemmules," which are furnished with capstan-like spicules, and are able to survive the winter. In April or May, they float away from the parental corpse and start new sponges. Some of these are short-lived males, others are more stable females. The ova produced by the latter, and fertilised by the cells of the former, develop into another generation of sponges, which in turn die away in autumn and give rise to "gemmules." The life-history thus illustrates "alternation of generations."

Development.—The development of sponges varies considerably in the different kinds. We shall follow that of a calcareous form. The ovum lying within the middle stratum, but close to a canal, is fertilised by a male cell, borne to it by the water. Fertilisation is followed by repeated division of the ovum; a hollow sphere of cells results, and this eventually escapes from the parent into the water. A short free-swimming life begins, in marked contrast to the completely sedentary state which will follow. One half of the minute sphere consists of ciliated cells, the other consists of larger, granular cells without cilia. The sphere is soon "dimpled in" or invaginated, and the ciliated hemisphere is surrounded by the other. A gastrula stage is thus reached—a two-layered thimble-like embryo. But the cilia are now inside, and the embryo fixes itself, mouth or blastopore downwards. This very disadvantageous shut-in condition cannot last; pores appear through the walls, perhaps somewhat pathologically at first; the water regains admission to the internal cavity; the cilia, which seem meanwhile to have disappeared in the absence of stimulus, regain their activity; an exhalent aperture (obviously in no sense the mouth) is ruptured at the apex of the dome; a middle stratum is derived from the inner layer, and its cells begin to form spicules:—the young sponge is made.

History.—The Sponges, as one would expect, date back nearly to the beginning of our geological record, for remains of a flinty form (*Protospongia*) have been discovered in the Cambrian rocks. Thence onwards they are almost always represented. Remains of calcareous sponges are almost confined to one peculiar set of large forms (Pharetrones), which are represented in the Devonian and several succeeding epochs. Schulze divides the sponge branch of the zoological tree into three, the calcareous forms to one side, the Hexactinellid—with triaxial flinty spicules—to the other, and between these two—the flinty sponges whose spicules have four axes (Tetraxonia) or one (Monaxonia), and, finally, the fibrous forms without spicules. Almost all zoologists regard the Sponges as the simplest descendants of the primitive many-celled animals, and there is also agreement that the sponge branch is a side offshoot leading up to nothing else.

Relation to other Organisms.—Sponges are living thickets in which many small animals play hide-and-seek. Some of the associations are practically constant and harmless, but some burrowing worms do the sponges much damage. Spicules, and offensive taste or odour doubtless save sponges from being more molested than they are. On the other hand, some sponges are borers, and others smother forms of life as passive as themselves. Several crabs are masked by growths of sponge on their shells, and the free transport is doubtless appreciated by the sponge—till the crab casts its shell. Within several sponges, minute Algæ constantly live, like the "yellow cells" within Radiolarians, in mutual partnership or symbiosis.

General Interest.—Sponges have been puzzles for centuries. Neither zoologists nor botanists would have them. Peyssonel regarded them as worm-nests, for were there not worms inside? Lamarck thought they were colonies of polypes, though the polypes were not to be seen; the popular mind classed them with seaweeds. A great step was made when Robert Grant first detected how the water-currents went in and out; since then our understanding of sponges has been rapidly progressive. They claim our interest, because they are the lowest many-celled animals, because they show tissues in the making, and because of the frequent beauty of their hard parts. The practical utility of a few soft forms is familiar.

DIAGRAM V.

THE LIFE-HISTORY OF SPONGES.

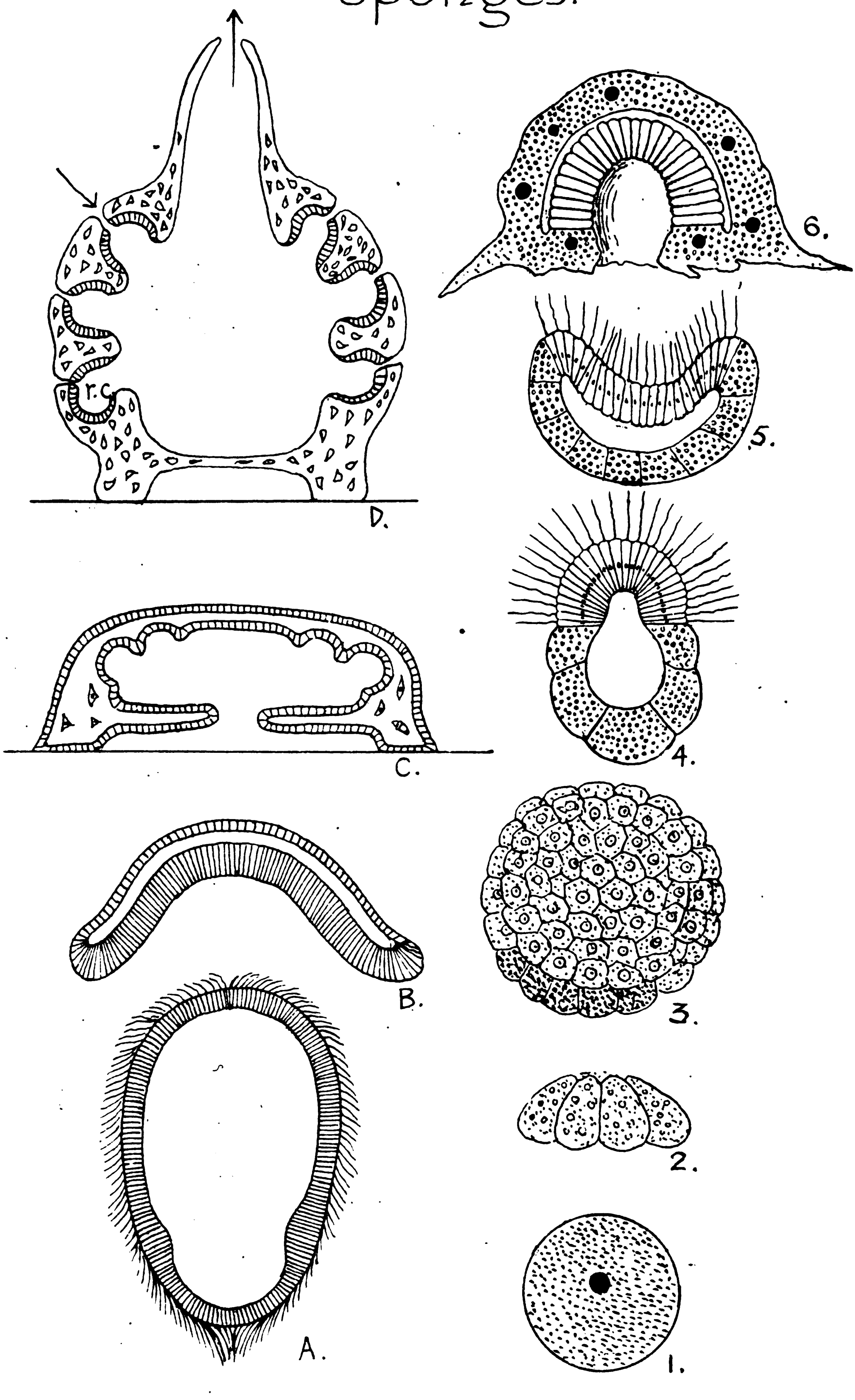
The right half of the diagram (1–6) is after F. E. Schulze, and applies to a calcareous sponge—*Sycandra raphanus.*

(1) Represents the ovum ; (2) is a side view of the stage with eight cells ; (3) shows the blastosphere, with a few granular cells at the lower pole ; (4) represents the free-swimming stage, the granular cells now occupying one hemisphere ; (5) depicts the formation of the gastrula, the ciliated cells becoming surrounded by the granular cells ; (6) shows a gastrula which has just fixed itself mouth downwards : the ectoderm or epiblast cells are amœboid, the endoderm or hypoblast cells have lost their cilia.

The left half of the diagram (A–D) is after Heider, and refers to *Oscarella* or *Halisarca lobularis*, one of the sponges without any hard parts.

(A) represents a section of a free-swimming ciliated blastula ; (B) shows the invaginated gastrula ; at (C) the gastrula has fixed itself, and the mouth or blastopore is being closed ; (D) is a diagrammatic section of the young sponge, with radial chambers (*r.c.*), with inhalent pores such as that one marked by the entrant arrow, with an exhalent osculum from which an arrow points outwards, and with mesoglœa developing between ectoderm and endoderm.

Sponges.



CHAPTER X.

CŒLENTERATA OR STINGING-ANIMALS.

THE title Cœlenterate is hardly worthy of this large series, which includes jellyfish and "zoophytes," sea-anemones and corals, and many other beautiful forms of life. The word Cœlenterate refers to the fact that the internal cavity of any of these animals is simply the food-canal (enteron), and not a true "body-cavity," but this is a somewhat technical fragment of information. The German word *Nesselthiere*, or stinging-animals, is at least more vivid, and it is justified by the fact that almost all the members of this series have stinging-cells, from which poisoned lassoes are thrown out, while only a few other animals possess this characteristic. The Stinging-animals are almost all either tubular and tentacled (polypoid) like the *Hydra* or the sea-anemone, or else floating bells or discs (medusoid) like the jellyfish, or, strangely enough, like each of these at different periods in their life-history.

Survey of the Series.—Representatives of all the chief divisions of Cœlenterates may sometimes be found in a single pool by the shore. In the nooks of the rocks are ruddy sea-anemones, which have been called sea-roses. Floating in the pool and throbbing gently is a jellyfish which has been washed in by the tide. Fringing the rocks are "zoophytes," or, if we read the word backwards, "plant-like animals." Besides these, and hardly visible in the clear water, are small transparent bells, some of which bear a strange relationship to the zoophytes. There are yet other exquisitely delicate, slightly iridescent globes—the comb-bearing Ctenophores, of which *Beroe* is a common type.

In inland ponds, however, we commonly find another

stinging-animal, a degenerate representative—the *Hydra*, which hangs from the stems and leaves of fresh-water plants. It is so simple in structure that we may start afresh with it, though in all likelihood it is rather at a terminus than at the beginning of the series.

This *Hydra*, which was first described in 1703 by Leeuwenhoek, and studied by some of the old naturalists, such as Rösel von Rosenhof and the Abbé Trembley, with natural eagerness, is in size very unlike the monster with which Hercules contended, for it is only from one-sixth to half an inch in length; but it is like the mythical form in its defiance of wounds. In fact, if we cut its tubular body into fragments, each part may reproduce the whole.

When the *Hydra* is feeding well, it buds off daughter forms, which remain for a while attached to the parent, but are eventually set adrift and establish themselves independently. A *Hydra* may be found with several daughter buds, and these before leaving the parent may themselves bear buds of yet another generation.

If you suppose the budding of *Hydra* continued almost indefinitely, you get an image of a "compound-Hydra,"—a hydroid colony, a zoophyte, such as you may find encrusting the shore rocks and many marine objects.

One of the most interesting and in some places commonest sights that you will see on the rocky shore is a hermit-crab within its usual buckie shell, but covered by a slightly pinkish crust of small polypes (*Hydractinia*), which may be found beautifully expanded in the still pool. They are like *Hydra* in many ways, but they are members of a budding colony, and are united at their bases by connecting roots or canals. In such a crowded colony of many hundreds, perfect liberty, fraternity, and equality are impossible; some are more favourably situated, and better fed, and consequently more completely developed than others; the fact at least is that the colony of *Hydractinia* shows division of labour among its members, some doing one thing, some another. Most numerous are nutritive "persons" like the *Hydra*, but besides these, and fed at their expense, are male or female reproductive persons which produce sperms or eggs, and eventually start new colonies. Again, however, there are long, slender "persons," likewise mouthless, but

rich in stinging-cells; they are perhaps the food-killers, defenders, and the sensitive critics of the colony. Lastly, the hard-skinned connecting roots are raised every here and there into little spines, which according to some naturalists are abortive "persons," like the thorns or abortive branches on the hawthorn hedge. When danger threatens, the other members of the colony cower down (for like the *Hydra* they are very contractile), and the spines are left projecting. So besides budding, another fact must be kept in mind if we are to understand Cœlenterates, namely, the tendency towards division of labour and difference of structure among the members of a colony.

The next step is more difficult to understand: it has to do with the connection between many a zoophyte and what are called swimming-bells or medusoids. In *Hydra*, individuals are budded off, but they are quite like the parent, and when they are set adrift they move very little. But in many zoophytes (Tubularians and Campanularians), among the ordinary buds which add to the extent and gracefulness of the colony, other buds appear which are after a time quite different, and are detached as locomotor swimming-bells. Now these bells or medusoids are sexual, they produce male and female elements, they give rise to embryos, each of which, after a brief life of freedom, settles down and starts a zoophyte colony. There is therefore an alternation in the life-history of such forms; a fixed, plant-like, asexual hydroid buds off locomotor, active, sexual medusoids, whose embryos start zoophytes afresh. This alternation of generations is another complication which must be borne in mind in the study of Cœlenterates.

But there are many medusoid organisms which are quite like the liberated locomotor buds of Tubularians and Campanularians, yet they seem to have no connection with any hydroids, and their embryos grow into forms like themselves. They are medusoids which are entirely free. Moreover, just as there are colonies of polypes, so there are colonies of medusoids, like the Portuguese-men-of-war, colonies in which the division of labour is not less beautiful than it is in *Hydractinia*.

From the swimming-bells or medusoids that we have just spoken about, it does not seem a great step to the jelly-

fishes which throb in the tide and are often cast in large numbers upon the beach, but the step is greater than it seems. Like as they are in habit, these two sets of animals are separated by marked anatomical differences. They form two independent series. Yet in a way they are parallel, for here again we find one type (*Pelagia*) always locomotor, another (*Aurelia*) whose early life is sedentary, and others (Lucernarians) which in their adult life are predominantly passive, mooring themselves by a stalk.

The Lucernarian jellyfish, and the sedentary juvenile stage of the common *Aurelia*, are of great interest, because they seem to point the way to the sea-anemones. These are sedentary polypes like the *Hydra*, but of much greater complexity, and with certain peculiarities of structure which suggest the alliance mentioned above. We may think of a medusoid as an inflated hydroid polype adapted for swimming, and there is a somewhat similar but vaguer relation between jellyfish and sea-anemone. And again, just as there are colonies of polypes of the *Hydra* type, so there are colonies of polypes belonging to the sea-anemone type, notably many corals and also dead-men's-fingers (*Alcyonium digitatum*), which is common in deep water around our coasts.

It is well to note explicitly that various polypoid types may form corals. In fact we may directly associate their sedentary passivity with the formation of a framework of carbonate of lime. Shells of lime are naturally connected with lazy life. (1) There are (Zoantharian) corals of the strictly sea-anemone type—madrepores, brain-corals (*Mæandrina*), and star-corals (*Astræa*), all important in the building of reefs. (2) Then there are other (Alcyonarian) corals whose polypes are like those of dead-men's-fingers—the "noble coral" of commerce (*Corallium rubrum*) with its solid red axis around which the individuals are clustered, the organ-pipe coral (*Tubipora musica*) in which the spicules are fused into external tubes, the blue coral (*Heliopora cærulea*), and many known as Gorgonids with flexible axes. (3) Again, there are other (Millepore) corals of the hydroid type, in which seven or eight small tactile "persons" are grouped in calcareous tubes round a larger nutritive "person," a series of which *Distichopora* is a well-known representative. Did space permit I should like to

speak of many of the interesting problems connected with corals. How do they get their carbonate of lime? Is that salt peculiarly abundant about coral reefs, or is there, as Irvine and Murray suggest, an interaction between the waste products of the polypes and the sulphate of lime abundant in sea-water? On what do they feed? Do their bright pigments, as Hickson suggests, enable them to utilise carbonic acid after the manner of plants? Then there is the struggle for standing-room among the coral polypes, and the struggle for existence among the many brightly-coloured animals which browse and hide on the reef.

Finally, as the corals are predominantly passive, so there is a climax of activity in the Ctenophores, which move by cilia united into combs, and often shine with that "phosphorescence" which is an expression of intensity of life in many active animals. There are hints of the way in which the Ctenophores may have arisen from a medusoid type.

General Characters of Cœlenterata.—(1) In Cœlenterata the symmetry of the gastrula is usually preserved; the long axis of the hydroid, sea-anemone, or jellyfish is the vertical axis of the gastrula, and the body is almost always radially symmetrical round this. (2) The simplest forms do not in structure rise much above the gastrula level; and the frequently jelly-like supporting substance or "mesoglœa," very generally found between the outer and inner layers of cells, cannot be regarded as a true mesoderm. (3) There is no body-cavity distinct from the primitive alimentary cavity of the gastrula and outgrowths from it. In these three respects the Cœlenterata differ from almost all the other Metazoa, to which the name Cœlomata is sometimes applied as a contrasted title. (4) There is an almost constant presence of offensive and defensive stinging-cells, whence the vivid German name for the class—nettle-animals. (5) Vegetative multiplication by budding is very common, especially in the passive hydroids, the plant-like appearance of which gave origin to the old name of zoophytes. (6) The life-history frequently illustrates, in its rhythm of activity and passivity, in its combination of free-swimming sexual and sessile asexual forms, what is known as alternation of generations. (7) In different classes "corals" occur, usually in passive forms, and usually with calcareous "skeletons."

General Classification.

The Cœlenterata are often classified as follows :—

A.	Hydrozoa.	Craspedota. Hydridæ, *e.g. Hydra*; Hydromedusæ (Hydroid colonies, often with free medusoids); Trachymedusæ (permanent medusoids); Siphonophoræ (free colonies of medusoids.	
		Acraspeda. True jellyfishes, *e.g. Aurelia, Cyanea.*	
B.	Actinozoa.	Alcyonaria, *e.g. Alcyonium* (Dead-men's-fingers.)	and related "corals."
		Zoantharia, *e.g. Actinia* (Sea-anemone.)	
C.	Ctenophora, *e.g. Beroe* and *Cestum Veneris* (Venus' Girdle).		

I prefer the following arrangement suggested by other authorities :—

A. Class Hydrozoa. Orders Hydridæ, Hydromedusæ, Siphonophoræ.
B. Class Scyphozoa. Sub-classes, Scyphomedusæ or Acraspeda; and Anthozoa or Actinozoa.
C. Class Ctenophora.

Survey of Types.

A. The Class Hydrozoa—
1. Order Hydridæ,
2. Order Hydromedusæ.
3. Order Siphonophoræ.

Illustrated (1) by *Hydra.*

General Life.—Various species of *Hydra*, especially the green *H. viridis* and the brown *H. fusca*, occur abundantly in fresh-water ponds. They are simple tubular animals with a crown of tentacles around the mouth. Large well extended specimens may measure one half to three-quarters of an inch in length, but they are as thin as needles. They contract into small knobs, which are not readily seen on the leaves of the duck-weed or other water plants, from the under surface of which they hang. The animal sways its body and tentacles backwards and forwards, but does not often move from its attachment. It can indeed loosen its base, lift itself by its tentacles, and stand on its head, but it evidently prefers a quiet life. Its food consists of small organisms, which are paralysed or killed by the stinging-cells on the tentacles, and

swept into the cavity by the ciliary action of the internal cells. Sometimes animals as large as water-fleas (*Daphnia*) are caught, but in this the *Hydra* makes a mistake. So simple is the *Hydra* that a cut-off fragment containing samples of the various kinds of cells in the body, and not too minute, may grow into an entire animal. Thus the *Hydra* may be artificially multiplied by being cut in pieces. It is not true, however, that when turned inside out (a delicate operation), ectoderm becomes endoderm, and *vice versa*; the two layers retain their characteristics, and the animal gradually rights itself.

General Structure.—The body is tubular, and the six to ten tentacles are continuous with its cavity. Of the two layers of cells, ectoderm and endoderm, the outer is transparent, the inner contains abundant pigment. On the tentacles especially, one can see, even with the low power of the microscope, numerous clumps of clear stinging-cells. The male cells are formed in several bulgings of the ectoderm, a short distance below the bases of the tentacles; a single ovum is borne in a larger bulging further down; but the male and female organs usually occur on different individuals, or on the same animal at different times. In favourable nutritive conditions, the *Hydra* bears daughter buds, which are eventually set adrift.

Minute Structure.—The outer-layer or ectoderm includes several different kinds of cells:—

(1.) Ordinary covering cells.

(2.) Muscular cells, with contractile basal processes which lie on the "middle lamina," between ectoderm and endoderm. There is no precise warrant for calling these cells "neuro-muscular."

(3.) Stinging-cells, nematocysts, or cnidoblasts, within each of which there lies a long eversible thread or lasso (cnidocil) bathed in poison.

(4.) Ganglionic cells, with many fine connections, especially with the stinging-cells.

(5.) Interstitial cells, which fill up chinks, and seem to grow into reproductive cells.

(6.) Glandular cells on the basal disc.

The inner-layer or endoderm is less varied in structure. Its cells are pigmented and ciliated, but in the absorption of food-particles active amœboid outflowings are seen. As the

food-particles are not changed before absorption, the digestion is intra-cellular. Some of the endoderm cells have muscular roots lying, like those of the ectoderm cells, on the middle lamina; a few cells near the mouth and base are described as glandular, and the presence of a few stinging-cells is also alleged.

The "middle lamina," representing the "mesoglœa," is a thin structureless plate, on each side of which lie the muscular roots of ectodermic and endodermic cells.

It is historically interesting to notice the important step which was made when, in 1849, Huxley definitely compared the outer and inner layers of the Cœlenterata with the epiblast and hypoblast which embryologists were beginning to demonstrate in the development of higher animals. Not long afterwards Allman applied to the two layers of Hydroids the terms ectoderm and endoderm, which we have often used.

The division of labour among the cells of *Hydra* is not very strict, but already the essential characteristics of ectoderm and endoderm are evident. We may summarise these as follows, comparing them with the characteristics of epiblast and hypoblast in higher animals:—

OUTER LAYER.	MEDIAN LAYER.	INNER LAYER.
The ectoderm forms— Skin-cells, Protective-cells, Ganglionic-cells, and Muscle-cells.		The endoderm forms— Digestive-cells lining the food canal, and also Muscle-cells.
The embryonic epiblast of higher animals grows into epidermis, nervous system, sense organs.	The mesoblast of higher animals becomes muscular, connective, skeletal tissue.	The embryonic hypoblast of higher animals always lines the digestive part of the food-canal.

The Reproductive Organs.—(*a*) From nests of dividing interstitial cells several clumps of spermatozoa or male elements are formed. They burst out at intervals through the swollen ectoderm.

(*b*) From a nest of interstitial cells, a single ovum is formed. In rare cases there are two. The ovum is at first amœboid and transparent, it seems to grow at the expense of neighbour cells. It becomes spherical, pigmented, and large, and forms a prominent bulging on the ectoderm.

Development.—The ovum bursts the thinned ectoderm, but remains for a while adherent to the parent. At this stage it extrudes polar bodies, and is fertilised. The fixed end may be called the vegetative pole; the spermatozoon enters at the opposite or animal pole.

The fertilised ovum undergoes complete segmentation, resulting, according to Kleinenberg, in a solid ball of cells or morula, but acccording to Kerschner, in a blastosphere. From the walls of this blastosphere, the latter observer saw cells migrating inwards, filling up the cavity and forming the future endoderm. This internal immigration from one pole of the blastosphere seems to occur in the development of a number of Cœlenterates. A triple protective envelope (chitinoid, vitelline, and mucous), is formed around the embryo of *Hydra viridis*, and thus ensheathed the embryo drops from the parent. Kleinenberg said that the superficial ectoderm was sacrificed in making the external chitinoid coat, but Kerschner denies this.

In the middle of the mass of cells a cavity develops, and the surrounding units are definitely arranged in two layers,—ectoderm and endoderm. The chitinoid layer bursts, and the embryo, still surrounded by the inner envelope, emerges. It elongates, acquires a mouth by rupture at one pole, and buds out tentacles. The inner envelope is lost, and the young *Hydra* fixes itself, and begins to live as its parents did. It is at the vegetative pole, apparently, that the mouth is formed.

Forms like Hydra.—Simpler than *Hydra* is *Protohydra*, a form without tentacles, occurring both in the sea and in fresh water. A similar fresh-water *Microhydra* has also been described. A strange animal—*Polypodium*—whose history is incompletely known, has been described as a parasite on the eggs of sturgeons.

The class Hydrozoa, illustrated (2) by several Hydromedusæ.

As *Hydra* is too simple to be typical of the majority of Hydrozoa, we must take account of those to which the name Hydromedusæ is properly restricted. This order includes the hydroid colonies or zoophytes which may be compared to *Hydræ* with many buds; but linked to these, and often included in their life-history, are medusoid forms which sometimes superficially resemble small jellyfish.

In many cases we know that these medusoid forms are the liberated

reproductive "persons" of fixed and asexual hydroid colonies, and that they produce ova and spermatozoa, from which develop embryos that start new zoophyte colonies. Thus the life-history illustrates *alternation of generations.*

If this were the case in all Hydromedusæ, there would be no difficulty in summing up the characters of the order. But it is not so. The puzzle is that many hydroid colonies do *not* give off medusoid bells, but have permanently attached and more or less reduced reproductive "persons." Besides, there are many free medusoids, anatomically similar to the detached buds, but without any connection with fixed zoophyte colonies.

(*a*) There are hydroid colonies with nutritive *Hydra*-like persons and other peculiarly modified reproductive persons or gonophores which are *not* set free as such. Such are the Hydrocorallinæ (millepores), and many zoophytes, especially Plumularians and Sertularians.

(*b*) There are hydroid colonies with nutritive *Hydra*-like persons and other peculiarly modified reproductive persons which *are* set free as sexual swimming-bells or medusoids. Such are many Tubularians and Campanularians.

(*c*) There are free medusoid animals, anatomically similar to the liberated bells above-mentioned, which have, however, no connection with hydroid colonies, but produce embryos which grow into other medusoids. These are called Trachymedusæ, and include two sub-orders, viz., the Trachomedusæ, *e.g.*, *Geryonia* and *Carmarina*, and the Narcomedusæ, *e.g.*, *Cunina* and *Æginopsis.*

For our present purpose, it is sufficient to regard the various kinds of Hydroids as "compound-Hydræ," supported by an external skeleton, with division of labour in the colony to this extent at least that the nutritive persons are different from the reproductive.

The Medusoid Type.

The medusoid is like a bell; the mouth is at the end of a prolongation (*manubrium*) which hangs like the clapper; the margin of the bell bears solid or hollow tentacles beset with stinging-cells; and a flap or shelf narrows the opening of the medusoid as the mouth of a bell would be narrowed if the margin were bent inwards. This flap (*velum* or *craspedon*) is one of the anatomical characters which distinguish medusoids (Craspedota) from jellyfish (Acraspeda or Scyphomedusæ) like *Cyanea.*

The surface of the medusoid is covered by ectoderm, with stinging-cells on the tentacles, muscle-cells on the manubrium, nervous cells around the margin; a ciliated endoderm lines the food-canals and extends into the tentacles; and an intermediate middle stratum is especially developed on the upper (ex-umbrellar) side of the medusoid as a gelatinous watery stuff, crossed by slim fibres,—being literally a middle jelly or mesoglœa.

Small organisms stung by the stinging-cells of the tentacles and gathered by the lips of the mouth, pass up the manubrium into the central cavity of the dome, are wafted by cilia down a number of radial canals, may reach one of the canals running around the margin, and are sooner or later absorbed by the endoderm cells, and subjected to intra-cellular digestion.

The contractions of ectodermic muscle-cells on the under (sub-umbrellar) surface of the bell cause slight alterations in shape, and thus the medusoid moves. Similar cells effect the movement of manubrium and tentacles.

The nervous system consists of a double ring of nerve-fibres around the margin of the bell. With these are associated ganglionic cells, which apparently control the muscular contractions.

Medusoids derived from Tubularian hydroids have eyes at the base of the tentacles, and are therefore called Ocellatæ. Those derived from Campanularian hydroids have auditory vesicles developed as pits on the velum, close to the inner nerve-ring, and are therefore called Vesiculatæ.

The reproductive cells develop by the side of the manubrium in ocellate medusoids, at the base of the manubrium or on the course of a radial canal in vesiculate medusoids. They always ripen in the ectoderm and often seem to arise there; but Weismann and others have shown that the reproductive cells of a medusoid derived from a hydroid, or of the reduced and fixed reproductive person of many hydroids, have considerable powers of migration, and may originate (sometimes apparently in the endoderm) in the hydroid colony, at some distance from the place where they are matured within the medusoid bud. The sexes are usually separate, and the commonest kind of free-swimming larva is a planula—a closed oval sac with two layers of cells, of which the outer are ciliated. In those medusoids which arise as the liberated sexual persons of a fixed asexual hydroid colony, the planula settles down and develops into a new hydroid.

The class Hydrozoa thus includes (*a*) Hydra and its relatives (Hydridæ); (*b*) hydroids and medusoids (Hydromedusæ), whether both these forms be united in one life-history or not; but it also includes (*c*) a third order (Siphonophoræ) of free-swimming medusoid colonies, with much division of labour, of which the Portuguese Man-of-War (*Physalia*) and *Velella* are instructive types. Some medusoids which multiply by budding, suggest how these Siphonophoræ might arise. The order is of great interest because of the division of labour which is illustrated among the members of colony. Thus there are usually nutritive, reproductive, sensitive, and natatory "persons" in one colony.

B. Class SCYPHOZOA— { Sub-class, Scyphomedusæ or Acraspeda.
Sub-class, Anthozoa or Actinozoa. }

The common Jellyfish—*Aurelia aurita*, one of the Scyphomedusæ.

This medusa is almost cosmopolitan, and in the summer

months occurs abundantly around the British coasts. We often see hundreds gently swimming in shoals, and many are washed shorewards and stranded on flat beaches. The glassy disc usually measures about four inches in diameter, but the maximum size is about twice as large. The jellyfish feeds on small animals, such as crustaceans, which are entangled and stung to death by the long lips.

External Appearance.—The animal consists of a gelatinous disc, slightly convex on its upper (ex-umbrellar) surface, and bearing on the centre of the other (sub-umbrellar) surface a four-cornered mouth, with four long much frilled lips. The circumference of the disc is fringed by numerous short hollow tentacles, by little lappets, and by a delicate muscular flap or *velarium.* Conspicuous in bright red are the four reproductive organs which lie towards the under surface. Nor is it difficult to see the numerous canals which radiate from the central stomach across the disc, the eight marginal sense-organs, and the muscle-strands on the lower surface.

The Three Layers.—The ectoderm which covers the external surface bears stinging-cells, especially on the tentacles, and to this layer belong sensory and nervous cells aggregated at eight centres, also a plexus of ganglion-cells beneath the skin on the under surface, and, finally, the muscle-cells. According to some, the ectoderm lines part of the mouth-tube or manubrium. The endoderm lines the digestive cavity, is continued out into its radiating canals, and is ciliated throughout. The mesoglœa is a gelatinous coagulation practically without cells. The whole animal is very watery, indeed the solid parts amount to not more than ten per cent. of the total weight.

Nervous System.—The nervous system consists (*a*) of a special area of nervous epithelium, associated with each of the eight sense-organs, and (*b*) of numerous much elongated bipolar ganglion-cells lying beneath the epithelium on the under surface of the disc. This condition should be contrasted with that in Craspedote medusoids, but too much must not be made of the contrast, for a nerve-ring is described in Cubomedusæ, one of the orders of Acraspedote jellyfish. In *Aurelia*, the sense-organs are less differentiated than in many other jellyfish. Each of the eight organs, protected in a marginal niche, consists of a pigmented spot,

a club-shaped projection with numerous calcareous "otoliths" in its cells, and a couple of apparently sensitive pits or grooves. We are not warranted in calling these organs "optic," "auditory," and "olfactory," in *Aurelia* at any rate. The sense-organs arise as modifications of tentacles, and are often called "tentaculocysts" or "rhopalia."

Muscular System.—Between the plexus of nerve-cells and the sub-umbrellar mesoglœa, there are cross-striped muscle-fibres, each of which has a large portion of non-contractile cell-substance attached to it. They lie in ring-like bundles, and by their contractions the medusa moves. Unstriped muscle-fibres are also found about the tentacles and lips.

Alimentary System.—The four corners of the mouth are extended as four much frilled "arms," each with a ciliated groove and stinging-cells, and with an axis of mesoglœa. They exhibit considerable mobility. Their crumpled and mobile bases surround and almost conceal the mouth. A short tube, the "manubrium" or gullet, connects the mouth with the central digestive cavity which occupies the centre of the disc. From this central chamber, sixteen gastro-vascular canals of approximately equal calibre radiate to the circumference, where they open into a circular canal, with which the hollow tentacles are connected. Eight of the radial canals are straight, but the other eight are branched, and thus in an adult *Aurelia* the total number of canals is large. These canals are really due to a partial obliteration of the gastric cavity, to a fusion of its ex-umbrellar and sub-umbrellar walls along definite lines. They are all lined by ciliated endoderm.

Where the manubrium or tube from the mouth passes into the central digestive cavity, there are four strong pillars of thickened sub-umbrellar material. Outside each of these pillars, and still near the base of the manubrium, there are four patches where the sub-umbrellar surface remains thin. These are the gastro-genital membranes, lined internally by germinal epithelium.

To the inside of these genital organs, within the digestive cavity, are four groups (*phacelli*) of mobile gastric filaments which are very characteristic of jellyfish. They are covered of course with endoderm—with ciliated, glandular, muscular, and stinging-cells.

Reproductive System.—The sexes are separate. The reproductive organs—ovaries or testes—consist of plaited ridges of germinal epithelium, situated on the four patches already mentioned, within sacs which are derived from and communicate with the floor of the gastric cavity. They are of a bright red colour, and at first of a horse-shoe shape, with the closed part of the curve directed outwards. Afterwards the ridges become circular and extend all round the walls of the sacs in which they lie. But the sub-umbrellar surface is modified beneath each genital sac in such a way that the sac comes to lie within a sub-genital cavity communicating with the exterior. The water which enters each of these washes the outside of the genital sacs, and perhaps helps in respiration. It must be clearly understood that the genital sacs containing the plaited ridges of germinal epithelium communicate with the gastric cavity only, while the sub-genital cavities containing water and enveloping the genital sacs communicate with the exterior only.

The ova and spermatozoa pass from the frills of germinal epithelium into the sacs, and thence into the gastric cavity. They find exit by the mouth, but young embryos may be found swimming in the gastro-vascular canals, and also within the shelter of the long lips.

Life-History of Aurelia.—The fertilised ovum divides completely and equally. A hollow ball of cells—a blastosphere or blastula—results. This undergoes invagination into a two-layered gastrula. But the mouth or blastopore of the gastrula closes, and a two-layered closed planula is thus formed. This planula is externally ciliated, and may be found in late summer swimming freely in the sea. But after a short time the planula settles down on a stone or seaweed, probably by its original blastoporal pole, acquires a mouth at the other pole, and proceeds to bud out tentacles—first four corresponding to the angles of the mouth (perradials), and then other four (interradials) between these, and then eight intervening adradials. Internally, the cavity of this "Hydra-tuba" or "scyphistoma" larva exhibits four inward-growing interradial ridges or tæniolæ. These correspond in position to the gastric filaments of the adult, and are probably comparable to the mesenteries of sea-anemones and other Anthozoa. The Hydra-tuba is only about an eighth of an

inch in height. It may give rise to other larvæ like itself by lateral buds near its base, or by the formation of creeping stolons from which buds are given off. This process must be distinguished from the multiplication by which the larva gives rise to the adult forms.

In late autumn, a remarkable change occurs. The scyphistoma elongates, and an annular constriction below the tentacles begins to separate off what lies above. Below the uppermost constriction another is formed, and gradually a dozen or more of these rings appear. This stage, often compared to a pile of saucers, is technically called a strobila. Each disc is separated off in its turn as a free-swimming Ephyra which becomes a jellyfish. The still undivided basal portion may rest awhile and then undergo further constriction.

The first Ephyra differs from those which come after it, since it bears the original tentacles of the Hydra-tuba. From its margin eight bifid lobes grow out, each embracing the base of a perradial or interradial tentacle. The bases of these eight tentacles become the sense-organs or rhopalia. The other eight (adradial) tentacles atrophy. On the Ephyræ which follow there are at first no tentacles—only the eight bifid marginal lobes which bear the sense-organs in their niches. The liberated Ephyræ grow rapidly, undergo some structural modifications, and eventually become small jellyfish.

Here, again, alternation of generations is illustrated. From the fertilised ovum, a fixed asexual Scyphistoma results. This grows into a Strobila, from which transverse buds or Ephyræ are liberated. Each of these grows into asexual *Aurelia*—producing ova or spermatozoa.

It is probable, as Hatschek suggests, that the Scyphistoma originally rested for a while and then floated off to become an adult. We may suppose this primitive life-history to have been succeeded by one in which the Scyphistoma divided transversely and set free one Ephyra, after which it rested, regained its tentacles, and then produced another, and so on in rhythmic succession. The "strobilation" or production of many Ephyræ in rapid succession, seems to represent an abbreviation of the primitive mode of development.

Near Relatives of Aurelia.—The common jellyfish is

DIAGRAM VI.

THE STRUCTURE OF CŒLENTERATA.

In the centre of the page is a typical gastrula (*Ga.*) ; on the lower half of the page are Hydrozoa, on the upper half are Scyphozoa.

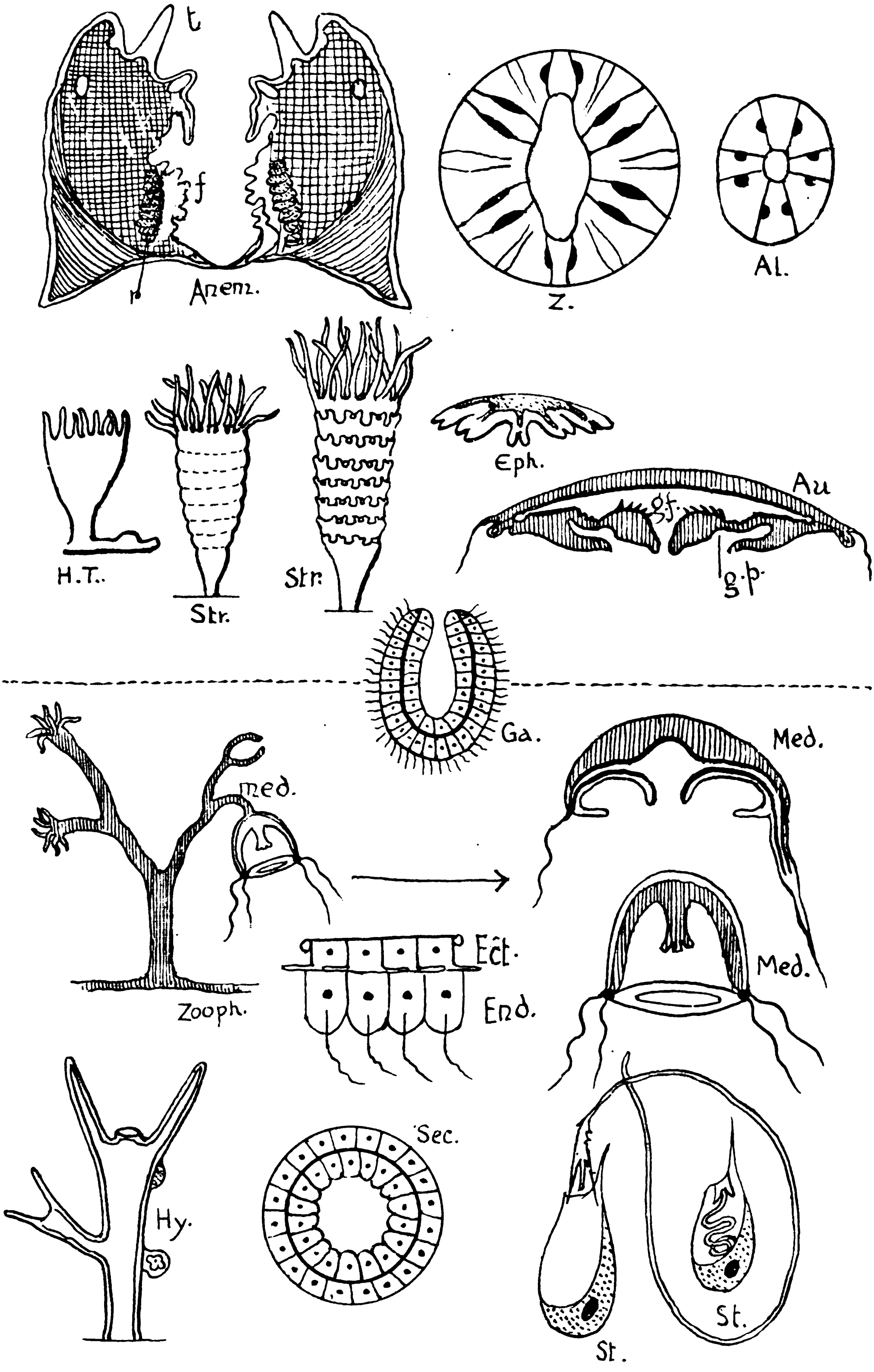
At the lower left-hand corner is a simple diagram of *Hydra* (*Hy.*), showing two tentacles, the mouth, a daughter bud, a testis, and the ovary. An ideal cross-section is represented by *Sec.*, while some of the characteristics of the ectoderm and endoderm are suggested above. At the right-hand corner are two stinging-cells (*St.*), one with the lasso ejected, the other with it still coiled in the cavity of the cell.

The diagram marked *Zooph.* suggests the origin of a medusoid bud (*med.*) from a hydroid colony, while on the opposite side of the page the nature of the velum, the darkened endodermic lining of the digestive cavity, and the hollowness of the tentacles are represented in two figures of medusoids (*Med.*). Above the line, at *Au.* is a section of *Aurelia*, showing the gastric filaments (*g. f.*) projecting into the digestive cavity, and the sub-genital pockets (*g. p.*) (after Ray Lankester). At *H. T.* is represented a Hydra-tuba with a basal stolon ; the two figures marked *Str.* show Strobila-stages ; *Eph.* is a liberated Ephyra.

At *Anem.* is a vertical section of a sea-anemone (after Hertwig). Two mesenteries are exposed ; each is perforated by two pores ; each bears muscles, and digestive filaments (*f.*), and reproductive organs (*r.*). The central cavity is bounded above by an inturned gullet ; two tentacles (*t.*) are also shown. To the right are two cross sections, of a Zoantharian (*Z.*) and of an Alcyonarian (*Al.*), showing how the muscles (represented by black marks) lie on the mesenteries

Diagram VI.

Coelenterata.



classed in the order Discomedusæ of the sub-class Scyphomedusæ or Acraspeda. Among its neighbours are the following:—*Cyanea*, some species of which are very large, *e.g.*, "an old example of *Cyanea arctica* which measured 7½ feet across the bell, with tentacles 120 feet long;" *Chrysaora*, a hermaphrodite, with diffuse sperm-sacs even upon the arms; *Pelagia*, with a direct development, *i.e.*, without Scyphistoma or Strobila stages; and the Rhizostomæ, *e.g.*, *Cassiopeia* and *Pilema*, in which the mouth is obliterated and replaced by numerous pores on the four double arms.

Contrast between a Hydrozoon and a Scyphozoon medusoid, between a Craspedote and an Acraspedote.

HYDROZOON. (CRASPEDOTA.)	SCYPHOZOON. (ACRASPEDA.)
The majority are small "swimming bells."	Many are large "jellyfish."
A flap or velum (craspedon) projects inwards from the margin of the bell.	No velum. (The *velarium* of *Aurelia* is a mere fringe, very inconspicuous in the adult, nor inturned.)
No tæniolæ, nor gastric filaments.	In the Scyphistoma there are four tæniolæ, from part of which the gastric filaments of the adult grow.
A double nerve-ring around the margin.	Eight separate nervous centres beside the sense-organs, and a sub-umbrellar nervous plexus.
Unhooded sense-organs either optic or auditory. They are usually derived from the skin, but the auditory sacs may be modified tentacles.	Sense-organs are modified tentacles, and probably have almost always a triple function. They are usually protected by a hood.
Reproductive organs on the radial canals or by the side of the manubrium. The reproductive cells are usually derived from the ectoderm.	Reproductive organs in special pockets on the floor of the gastric cavity. The reproducive cells arise in the endoderm.
With the exception of the Trachymedusæ, all arise as the liberated reproductive persons of Hydroid colonies.	Have no connection with hydroids, but may have a small sedentary polype stage (or Scyphistoma,) in the course of their life-history.
True Hydrozoa.	Probably more nearly related to Anthozoa than to Hydrozoa.

Class Scyphozoa. Sub-Class, Anthozoa or Actinozoa.

TYPE.—A Sea-Anemone, such as *Tealia crassicornis.*

Most sea-anemones live fixed to the rocks about low-water mark. Some, *e.g.*, *Tealia crassicornis*, are often half-buried in sand; a few are unattached. The sedentary

forms are able to shift their position by short stages. They feed on small animals,—Molluscs, Crustaceans, Worms, which are caught and stung by the tentacles, but many must depend largely on minute organisms, while others may be seen trying to engulf molluscs decidedly too large for them. A few anemones, without pigment or with little, have symbiotic Algæ in their endoderm-cells; the bright pigments of many others seem to help in respiration. Besides the normal sexual reproduction (in which the young are sometimes developed within the parent), some sea-anemones exhibit a power of asexual multiplication by detaching portions from near the base, and fission occurs in a few forms.

External Appearance—The cylindrical body is fixed by a broad base; it bears circles of hollow tentacles around the oral disc; the mouth is usually a longitudinal slit. The tentacles are contracted when the animal is irritated, and the whole body can be much reduced in size. Water may pass out gently or otherwise by a pore at the tip of each tentacle, and long white threads, richly covered with stinging-cells, are often ejected by holes on the walls of the body. In certain states, especially if dying, the sea-anemone protrudes its gullet and turns itself partially inside out.

General Structure of the Body.—The Anthozoon polype differs markedly from the hydroid—not only because an invagination from the oral disc inwards has formed a gullet; but also because a number of partitions or mesenteries extend from the body-wall towards this gullet. Some of the partitions are "complete," *i.e.*, they reach the gullet; others are "incomplete," *i.e.*, do not extend so far inwards. The complete mesenteries are attached to the oral disc above, to the side of the gullet, and to the base, and all the mesenteries are ingrowths of the body-wall. The cavity of the anemone is thus divided into a number (some multiple of six) of radial chambers. These are in communication at the base, so that food-particles from the gullet may pass into any of the chambers between the partitions. Moreover, each partition is perforated, not far from the mouth, by a pore, besides which there is often another nearer the body-wall. The tentacles are continuous with the cavities between the mesenteries, and thus all the parts of the body are in

communication. The mouth is usually a longitudinal slit, and its two corners are often richly ciliated and continued into grooves ("siphonoglyphes") down each side of the gullet. Along these two grooves, and by these two corners, food-particles usually pass in; but in some it seems that one side is an incurrent, the other an excurrent channel. Occasionally, only one corner of the mouth and side of the gullet is thus modified. The gullet often extends far down into the cavity of the anemone, and admits of a certain amount of extrusion. The mesenteries bear (*a*) mesenteric filaments; (*b*) retractor muscles; (*c*) ridges of reproductive cells, almost always either ova or spermatozoa, rarely both; and (*d*) in some cases offensive threads (acontia), rich in stinging-cells, and extrusible through holes in the body-wall. The mesenteric filaments seem to be closely applied to the food and secrete digestive juice. Sea-anemones have no sense-organs; the sapphire-beads, which are so well seen at the bases of the outermost tentacles of the common *Actinia mesembryanthemum*, are really batteries of stinging-cells. The nervous system is uncentralised, and consists of superficial sensory cells connected with a plexus of sub-epithelial ganglion-cells.

The Layers of the Body.—The ectoderm which clothes the exterior is continued down the inside of the gullet. The endoderm lines the whole of the internal cavity, including mesenteries and tentacles. The mesoglœa is a supporting plate between these two layers, and forms a basis for their cells.

The ectoderm consists of ciliated, sensory, stinging, and glandular cells, and also of sub-epithelial muscle and ganglion cells based on the mesoglœa, but mainly restricted to the circumoral region.

The endoderm consists mainly of flagellate cells, with muscle-fibres at their roots. These form the main muscle-bands of the wall, the mesenteries, and the gullet. Nor are glandular and even sensory cells wanting from the endoderm.

The Mesenteries.—In Sea-Anemones and nearly related Anthozoa twelve primary mesenteries are first formed. These are grouped in pairs, and the cavity between the members of a pair is called intra-septal, in contrast to the inter-septal cavities between adjacent pairs. In these inter-septal chambers other mesenteries afterwards appear in pairs. Two pairs of mesenteries, however, differ from all the rest, those, namely, which are attached to each corner of the mouth and to the corresponding grooves of the gullet. These two pairs of mesenteries are called "directive," and they divide the animal into bilaterally symmetrical halves. Anatomically, a pair of directive mesenteries differ from the other paired mesenteries, because the retractor muscles

which extend in a vertical ridge along them, are turned away from one another and run on the inter-septal surfaces, whereas in the other mesenteries the retractor muscles run on the intra-septal surface, those of a pair facing one another. The arrangement of these muscles is of great importance in classifying Anthozoa. It is probable that the mesenteries are homologous with the tæniolæ of jellyfish, and the mesenteric with the gastric filaments.

Development.—Comparatively little is known in regard to the early stages of development in sea-anemones. From the fertilised ovum, a blastosphere may result which by invagination becomes a gastrula. Or the two layers may be established by a process known as delamination, in which the cells are divided into an inner endodermic and an outer ectodermic layer.

Related Forms.—The Sea-Anemones are classified in the sub-class Anthozoa or Actinozoa, and along with many corals are distinguished as Zoantharia or Hexacoralla from the Alcyonaria or Octocoralla, like *Alcyonium* and related corals. This contrast is not perfectly satisfactory, but it rests on such distinctions as the following :—

ANTHOZOA OR ACTINOZOA.

ZOANTHARIA, HEXACORALLA, *e.g.*, SEA-ANEMONE.	ALCYONARIA, OCTOCORALLA, *e.g.*, DEAD-MEN'S-FINGERS.
Many are simple, many colonial.	All colonial, except a small family including *Monoxenia* and *Haimea*.
Tentacles usually simple, usually some multiple of six, often dissimilar.	Tentacles eight, feathered, uniform.
Mesenteries usually some multiple of six, complete and incomplete.	Mesenteries eight, complete.
Retractor muscles never as in Alcyonaria.	Retractor muscle always on one (ventral) side of each mesentery.
Two gullet grooves or siphonoglyphes, or only one.	One (ventral) gullet-groove or siphonoglyphe, or none.
Dimorphism only in some Antipatharia, and in one Madrepore coral.	Occasional dimorphism among members of a colony.
Calcareous skeleton if present is derived from the basal ectoderm.	There are usually calcareous spicules (of ectodermic origin) in the mesoglœa.
Types.	*Examples.*
Actiniaria. Sea-Anemones.	*Alcyonium* (Dead-men's-fingers), with diffuse spicules of lime.
Madreporaria. Reef-building corals.	*Tubipora* (Organ-pipe coral), with spicules fused into tubes and transverse platforms.
Antipatharia. Black corals.	*Corallium rubrum* (Red-coral), with an axis of fused spicules.
	Isis, with an axis of alternately limy and horny joints.
	Pennatula (Sea-pen), a free phosphorescent colony, with a "horny" axis possibly endodermic.
	Heliopora, blue coral.

Coral-Making.—We have already noticed that there are "corals" among the Hydrozoa, viz., the Millepores. Leaving these out of account, we have to recognise that both divisions of Anthozoa include many corals.

With the doubtful exception of the Sea-pens and their allies, in which the axial skeleton is believed by some to be endodermic, the "coral" is due to *ectoderm* cells which either remain in the ectoderm or wander into the mesoglœa.

We may arrange "corals" according to different bases of classification:—

According to Composition—

(1.) Discontinuous calcareous spicules—*Alcyonium*, etc; these may also occur along with some forms of (2).

(2.) Continuous skeleton.

(*a*) Organic and horny, *e.g.*, axis of many Gorgonids, axis of Pennatulids.

(*b*) Horny and calcareous, *e.g.*, axis of *Isis*.

(*c*) Wholly calcareous, in the great majority.

According to extent of the hard parts—

(1.) Diffuse spicules, *e.g.*, *Alcyonium*.

(2.) Fused in an external tube, *e.g.*, *Tubipora* (Organ-pipe coral). } "Sclerodermic."

(3.) Fused in an axis, *e.g.*, *Corallium rubrum* (Red coral). } "Sclerodermic."

(4.) Invading the outer wall (theca), the base, and *between* the mesenteries, and often forming a central pillar (columella), *e.g.*, massive reef-building corals. } "Sclerobasic."

According to position of the hard parts—

(1.) "Exoskeletal," more or less directly continuous with the ectoderm, *e.g.*, in Madrepore corals (reef-builders), like *Astræa*, *Fungia*, *Madrepora*; in Gorgonids, *Gorgonia* and *Isis*.

(2) "Mesoskeletal," *i.e.*, in the mesoglœa,
e.g., spicules of *Alcyonium*,
fused spicules of *Tubipora*,
axis of *Corallium*.

SYSTEMATIC CLASSIFICATION OF THE CŒLENTERATA.

The Cœlenterata are aquatic and almost wholly marine animals which differ from higher Metazoa in retaining the symmetry of the gastrula, and in having no definite mesoderm nor body-cavity. Associated with the ectoderm there are stinging-cells, and the nervous and muscular cells remain epithelial. The reproductive elements may arise from the ectoderm or from the endoderm. There are two types—

the hydro-polypes like *Hydra*, and the scypho-polypes like *Actinia*, with each of which a medusoid type is associated, while both are referable to a gastrula-like ancestor. Budding is common, alternation of generations is frequent, and both the great orders include "Corals."

A. Class Hydrozoa :—Orders Hydridæ, Hydromedusæ, Siphonophoræ.
B. Class Scyphozoa :—Sub-classes Scyphomedusæ or Acraspeda, Anthozoa or Actinozoa.
C. Class Ctenophora.

A. Class Hydrozoa.

There are two types, polypoid and medusoid, which may be combined in one life-history. The mouth leads directly into the gastric cavity. The mesoglœa is simple and without migrant cells. The reproductive cells are usually ectodermic.

1. Order Hydridæ. Solely polypoid,—*Hydra*, *Protohydra*, *Microhydra*, *Polypodium*.
2. Order Hydromedusæ. Polypoid colonies with special sexually reproductive persons, which are often liberated as medusoids.
   (*a*) Tubularians, in which the polypes are not enclosed in the protective sheath which may surround the colony (gymnoblastic).
   The sexually reproductive persons are often liberated as "ocellate" medusoids, Anthomedusæ ;
   or sometimes remain attached to the colony as fixed gonophores.
   Examples :
   Syncoryne sarsii liberates the medusoid *Sarsia tubulosa*.
   Bougainvillea ramosa liberates the medusoid *Margelis ramosa*.
   Cordylophora lacustris has no free medusoid.
   Tubularia larynx has no free medusoid.
   (*b*) Campanularians, in which the polypes are enclosed in cups, continuous with the protective sheath which surrounds the colony (calyptoblastic).
   The sexually reproductive persons are often liberated as "vesiculate" medusoids,—Leptomedusæ ;
   or sometimes remain attached to the colony as fixed gonophores.
   Examples.—The hydroid *Campanularia geniculata* liberates the medusoid *Obelia geniculata*.
   Laomedea caliculata has no free medusoid.

(*c*) The Hydroid colonies known as Plumularians and Sertularians have no free medusoids.
(*d*) The divergent Hydrocorallinæ, *e.g.*, *Millepora* and *Stylaster*, with calcareous skeletons, seem to have gonophores.
(*e*) On the other hand, the Trachymedusæ exist only as medusoids, *e.g.*, *Geryonia*, *Carmarina*, *Cunina*, *Aeginopsis*.

3. Order Siphonophoræ. Free-swimming colonies of modified medusoid persons (medusomes) with much division of labour.
e.g. *Physalia* (Portuguese Man-of-War) and *Diphyes*; *Vellela* and *Porpita*.

B. Class Scyphozoa.

There are two types—polypoid and medusoid—very rarely occurring in one life-history. The gastric cavity has partitions with gastric or mesenteric filaments, and there is more or less of an ectodermic gullet. The mesoglœa generally contains migrant cells. The reproductive cells are endodermic.

I. Sub-Class Scyphomedusæ or Acraspeda—
Jellyfish with gastric filaments, sub-genital cavities, no velum, etc. (see before). These are classified in various ways:—Stauromedusæ, *e.g.*, *Lucernaria*; Peromedusæ, *e.g.*, *Pericolpa*; Cubomedusæ, *e.g.*, *Charybdea*; Discomedusæ, *e.g.*, *Aurelia*, *Cyanea*, *Pelagia*, *Pilema* or *Rhizostoma*.
Pelagia develops directly without polypoid stage.
Aurelia passes through Scyphistoma and Strobila polypoid stage.
Lucernaria is sedentary, and fixes itself by a stalk. It thus resembles Anthozoa in habit as well as in structure.

II. Sub-Class Anthozoa or Actinozoa—
Polypoid, with well-developed gullet and mesenteries, with circum-oral tentacles, etc. (see before).
a. Zoantharia.
Actiniaria. Sea-Anemones, *e.g.*, *Actinia*, *Anemonia*, *Tealia*, *Cereanthus*, etc.
Madreporaria. Stone or reef corals, *e.g.*, *Astræa*, *Madrepora*, *Fungia*, *Mœandrina*.
Antipatharia. So-called black corals, with a horny axial skeleton, and occasional dimorphism between nutritive and reproductive "persons," *e.g.*, *Antipathes*.
b. Alcyonaria, *e.g.*, *Alcyonium* (Dead-men's-fingers).
Tubipora (Organ-pipe coral), *Corallium* (Red coral), *Gorgonia*, *Pennatula* (Sea-pen), *Monoxenia* (non-colonial).
Among the Anthozoa are also included the extinct or almost entirely extinct Rugose corals (Tetracoralla), with numerous septa in some multiple of four.

C. Class Ctenophora.

Delicate free-swimming organisms, generally globular in form, moving by means of eight meridional rows of ciliated plates or comb-like combinations of cilia. The stinging-cells are usually modified into "adhesive cells." The mouth is at one pole, and leads into an ectodermic gullet. The gastric cavity is usually much branched. The middle stratum is well developed, and includes muscular and connective cells. At the aboral pole, there is a sensory organ, including an "otolith" which seems of use in steering. Here, also, there are two excretory apertures. Except in *Beroe* and its near relatives there are two retractile tentacles. All are hermaphrodite. The development is direct. They are pelagic, very active in habit, carnivorous in diet, and often phosphorescent. According to Lang, they have affinities with Planarian "worms," but this view is not generally accepted.

Examples.—(*a*) With tentacles, *Cydippe* and the ribbon-shaped Venus' Girdle (*Cestum Veneris*).
(*b*) Without tentacles, *Beroe*.

Appendix : Mesozoa.

We are not at present warranted in attaching much importance to some very simple parasites which Van Beneden has called Mesozoa. They may be very primitive and persistent modified gastrulæ, hence some would call them Gastræadæ; while Van Beneden's title suggests their position between Protozoa and Metazoa. Hatschek, comparing them with equal justice to precociously reproductive planulæ, calls them Planuloidea. On the other hand, they may have degenerated by parasitism from Turbellarian worms.

They have no mouth or alimentary cavity. The ectoderm is ciliated. The endoderm consists of a single large cell (in Dicyemidæ), or of a few (in Orthonectidæ), and from it the reproductive elements are produced. What is known of their life-history is peculiar.

Examples.—Dicyemidæ, *e.g.*, *Dicyema*, in the kidneys of Cuttle-fish.
Orthonectidæ, *e.g.*, *Rhopalura*, in Brittle-stars, Turbellarians, and Nemerteans.

General Life of Cœlenterata.—Almost all the stinging-animals live in the sea. The following are fresh-water forms :—the common *Hydra*, the minute *Microhydra* without tentacles, the strange *Polypodium* which in early life is parasitic on sturgeons' eggs, the compound *Cordylophora* occurring in canals and in brackish water, and the fresh-water

Medusoid (*Limnocodium*) found in a tank at Kew. Most of the active swimmers live near the surface, but there are also deep-water inhabitants of active disposition. Many polypes anchor upon the shells of other animals which they sometimes mask, and there are most interesting constant partnerships between hermit-crabs and sea-anemones. The reef-building corals fringe the coasts, or rise upon the tops of submarine volcanoes, but nowadays they are restricted to an equatorial zone, whose boundary lines are marked by a minimum average temperature of 60° Fahr., nor are they ever found alive at depths exceeding twenty fathoms. The red-coral of commerce is obtained from the Mediterranean and from the Atlantic off the N.W. of Africa.

As to diet, the active Ctenophores are carnivorous, attaching themselves by adhesive cells to one another or to other small animals; many of the larger forms, *e.g.*, sea-anemones and jellyfish, are able to engulf booty of considerable size; the majority, however, feed on small organisms, in seizing and killing which the tentacles and stinging-cells are actively used; but what the corals eat no one seems to know.

History.—Of corals, as we would expect, the rocks preserve a faithful record, and we know, for instance, that in the older (Palæozoic) strata, they were represented by a distinct series (*Rugosa* or *Tetracoralla*), of which we have now only two or three survivors. We often talk of the imperfection of the geological record, and rightly, for much of the library has been burned, many of the volumes are torn, whole chapters are wanting, and many pages are blurred. But this imperfect record sometimes surprises us, witness the quite distinct remains of ancient jellyfish, which animals, as we know them now, are blubber-like and apparently little more than animated sea-water. It is right, too, that we should grasp the conception, with which Lyell first impressed the world, of the uniformity of natural processes throughout the long history of the earth. Thus, in connection with Cœlenterates, we learn that there were great coral reefs in the incalculably distant past, just as there are coral reefs still. So in the Cambrian rocks, which are next to the oldest, there are on sandy slabs markings exactly like those which are now left for a few hours, when a large jellyfish

stranded on the flat beach slowly melts away. On the other hand, some forms of life which lived long ago, seem to have been very different from any that now remain, witness, for example, the very abundant Graptolite fossils, which, though probably Cœlenterates, do not fit well into any of our modern classes.

Pedigree.—As to the pedigree of the stinging-animals, the facts of individual life-history, and the scientific imagination of naturalists, help us to construct a genealogical tree—a hypothetical statement of the case. One fact is practically certain, that the ancestral many-celled animals—ancestral to Sponges, Cœlenterates, and all the rest—were small two-layered tubular or oval forms. The many-celled animals must have begun as clumps of cells; the question is, what sort of clumps—spheres of one layer of cells, or mouthless ovals, or little discs of cells, or two-layered thimble-like sacs? Possibly there were many forms, but Hæckel and other naturalists were led to fix their attention especially on the two-layered sac or *gastrula*, because this form keeps continually cropping up as an embryonic stage in the life-history of animals whether sponge or coral, earthworm or starfish, mollusc or even vertebrate, and also because this is virtually the form which is exhibited by the simplest sponges (Ascones), the simplest Cœlenterates (*Hydra*), and even by the simplest "worms" (Turbellarians). In fact, we take sponges first, stinging-animals second, and "worms" third, because their simplest forms are least removed from this gastrula type,—the hypothetical ancestral *Gastræa*.

Well, if we begin in our survey from such a gastrula-like ancestor, the probabilities are certainly in favour of the supposition that it was a free-swimming organism. A gradual perfecting of the locomotor characteristics might yield the two medusoid types of which we have already spoken. But we know that the common jellyfish *Aurelia* has a prolonged larval stage which is sedentary, vegetative, and prone to bud. If we suppose with W. K. Brooks that many forms, less constitutionally active than others, relapsed into this sedentary state, with postponed sexuality, and with a preponderant tendency to bud, we can understand how polypes arose, and these of two types, one nearer the jellyfish and Lucernarians and leading on to sea-anemones and corals, the other nearer the

swimming-bell type and leading on to a terminus in *Hydra.* It is certainly suggestive that we have jellyfish wholly free (*Pelagia*), jellyfish with a sedentary larval life (*Aurelia*), jellyfish predominantly passive (*Lucernaria*), and related polypes (Sea-Anemones, etc.) which only occasionally rise into free activity; while in the other series we have medusoid types always free, others which are liberated from (Campanularian and Tubularian) sedentary hydroids, other (Sertularian and Plumularian) zoophytes whose buds though often medusoid-like are not set free, and finally, *Hydra*, which though it may creep on its side, or walk on its head, is predominantly a sedentary animal, without any youthful free-swimming stage.

GENERAL SCHEME OF CŒLENTERATA.

	Predominantly Passive.	Predominantly Active.
		C. Ctenophora, *e.g.*, Beroe, Venus' Girdle. (Active climax.)
B. Scypho-zoa. ↑	II. Anthozoa or Actinozoa. (Zoantharia) Sea-Anemones and related corals. (Alcyonaria) Dead Men's Fingers and related corals.	The embryos are free-swimming, and a few adults also are locomotor.
	I. Scyphomedusæ or Acraspeda. *c.* Adult Lucernarians usually attached. *b.* Sedentary larval stage. *a.* No fixed stage.	 *c.* Free embryos. *b.* Aurelia type of jellyfish. *a.* Pelagia type of jellyfish.
	ANCESTRAL	GASTRÆA.
↓ A. Hydro-zoa.	1. No fixed stage. 2. No fixed stage. 3. Many Hydroid colonies. (Campanularians and Tubularians.) 4. Many Hydroid colonies, whose reproductive persons are not liberated. 5. Coralline Millepores.	1. Trachymedusæ (always locomotor). 2. Siphonophoræ (locomotor colonies of modified medusoids). 3. Liberated reproductive "persons" of these colonies. 4. No free stage, except as embryos. 5. No known free stage.
	6. Hydra without any specially locomotor stage.	

CHAPTER XI.

WORMS.

THIS title is justifiable only as a popular name for a shape. The animals included under it form a heterogeneous mob with little in common. There is no class of "worms," but a collection of classes whose relationships are very imperfectly discerned. But if we understand this, there can be no harm in using the title, which is certainly convenient.

We have seen that the Cœlenterates present radial modifications of the primitive gastrula-type; many "worms" are longitudinal and bilateral modifications of the same. The gastrula is elongated, however, not in the direction of the original long axis, but at right angles to it.

We have also noticed that "worms" were the first multicellular animals to move head-foremost. They began to move in one direction, acquiring head and sides. Moreover, as one end constantly experienced the first impressions of external objects, sensitive and nervous cells would tend to be most developed in that "head" region. Thus a brain arose. The nerve-cords, which are lateral in the simpler forms, are combined along the mid-ventral line in the higher.

Again it may be noted that worms begin the series of Cœlomate animals. In other words, they are the first to acquire a body-cavity or cœlome, and a definite middle layer or mesoderm.

It is not at present possible to have much confidence in preferring one arrangement of the many classes of worms to another, but the following order will be observed here. It is at least certain that the number of great divisions cannot at present be more reduced without giving a false simplicity to the facts.

A. TURBELLARIA. Planarians, etc. TREMATODA. Flukes, etc. CESTODA. Tapeworms, etc.	Plathelminthes, Scolecida, or Flat-worms.
B. NEMERTEA. Ribbon worms.	
C. NEMATODA. Thread worms, including the *Gordius* type. ACANTHOCEPHALA. *Echinorhynchus.*	Nemathelminthes, Round worms.
D. CHÆTOPODA. Bristle-bearing worms. Oligochæta. *e.g.*, Earthworms. Polychæta. Marine worms. Echiuridæ. *e.g.*, *Echiurus* and *Bonellia* (sometimes called Gephyreans). Appended to Chætopoda are— (1) Primitive forms—Archi-annelida. (2) Myzostomata—parasitic on Crinoids. DISCOPHORA or HIRUDINEA. Leeches.	Annelids or Ringed Worms.
E. Provisionally appended to the Annelid series— Chaetognatha. Arrow-worms. *Sagitta* and *Spadella*. Rotatoria. Rotifers.	
F. There remain— Sipunculoidea, *Sipunculus*, etc. (sometimes included with Echiuridæ as Gephyreans). Phoronidea. *Phoronis.* Polyzoa or Bryozoa. Sea Mats, etc. Brachiopoda. Lamp-shells.	Perhaps related to one another.

First Series. FLAT-WORMS OR PLATHELMINTHES—	Class TURBELLARIA, Planarians, etc. Class TREMATODA, Flukes, etc. Class CESTODA, Tapeworms, etc.

Class TURBELLARIA. Planarians, etc.

The Turbellarians are simple "worms" living in fresh, brackish, or salt water. Many of them are called Planarians.

Like other Plathelminthes (flat-worms), they are bilaterally symmetrical, un-segmented, with lateral nerve-cords, and with primitive excretory tubes.

Their more precise characteristics are:—

(1) The ectoderm is ciliated, as is natural enough in free-living simple animals, and it contains peculiar rod-like bodies (rhabdites), and, very rarely, stinging-cells.

(2) The nervous system consists of two ganglia in the head-region (which is obviously the region most stimulated), and of two nerve strands running backwards, but not united in a double ventral nerve-cord; there are usually simple sense-organs.

(3) The food canal has a muscular pharynx, is often branched, and is always blind. They are carnivorous.

(4) There is no development of special respiratory or circulatory organs; the body-cavity is represented at most by small spaces; the excretory system usually consists of two branched canals, ending internally in ciliated cells.

(5) With the exception of two genera, they are hermaphrodite, and the reproductive organs usually show some division of labour, *e.g.*, in the occurrence of a yolk gland, which seems to be an over-nourished portion of the ovary.

Classification of noteworthy forms of Turbellarians.

Order 1. Polycladidea. Marine Planarians. Large flat leaf-like forms, with numerous ovaries and testes, without yolk-glands, mostly with two genital apertures. The food-canal is much branched.

e.g., *Cycloporus.*
Leptoplana.

Order 2. Tricladidea. Fresh-water, marine, and terrestrial Planarians. Elongated flat forms; the mouth and tubular pharynx lie behind the middle of the body; two ovaries, numerous yolk-glands and testes, and a common genital aperture. The food-canal divides into two main lateral loops, which are themselves branched.

e.g., *Planaria* and *Dendrocœlum* (in fresh-water); the former sometimes divides transversely.

Gunda segmentata (marine) with *internal* segmentation.

Geodesmus and *Bipalium* (in damp earth).

These two orders are often called Dendrocœl (with branched gut) in contrast to the following Rhabdocœl forms (with straight gut).

Order 3. Rhabdocœlidea. Small fresh-water and marine forms. The body tends to be cylindrical. The food-canal is either very slightly branched, or quite straight, or absent.

e.g., *Vortex*.

Microstoma, unisexual, forming temporarily united asexual chains, sometimes of sixteen individuals, suggesting the origin of a segmented type.

Stenostoma, also unisexual.

Graffilla, parasitic in habit (*cf.* next class).

Convoluta, without any food-canal, but containing green cells which some regard as symbiotic Algæ.

Relationships.—Lang maintains that there are marked affinities between these simple animals (especially *Cœloplana* and *Ctenoplana*) and the Ctenophora.

The Turbellarians are also related to the next class—the Trematodes.

Class TREMATODA. Flukes, etc.

The Trematodes are leaf-like or roundish external or internal parasites. With their mode of life we may associate the absence of cilia on the surface of the adults, the well-formed and apparently cellular "cuticle," the presence of attaching suckers with or without hooks, and the rarity of sense-organs. It is likely that they have arisen from free Turbellarian-like ancestors, and they certainly resemble the former class in being all of one piece (unsegmented), in having a pair of anterior nerve-centres from which nerves pass backward and forward, in the rudimentary nature of the body-cavity, in the ramifying system of fine excretory canals, in the hermaphrodite and usually complex reproductive system. The alimentary canal is usually forked, often much branched, and always ends blindly. In many cases, at least, the animals are self-impregnating. The development of the external parasites is usually direct, of the internal parasites usually indirect, involving alternation of generations. They occur in or on all sorts of Vertebrates, but those which have an indirect development and require two hosts to complete their life-cycle, often pass part of

DIAGRAM VII.

FLUKE AND TAPEWORM.

The lower half of the diagram shows the life-history of *Distomum*.

a, is the embryo still within its egg-shell.
b, is the free-swimming ciliated larva with eye-spots.
c, is the sporocyst with rediæ formed within it.
d, is a single redia with reproductive cells.
e, is another redia with more rediæ within it.
f, is a redia with cercariæ formed within it.
g, is a cercaria, with tail, forked gut, and two suckers.
h, is a young fluke, without tail, with branched gut.

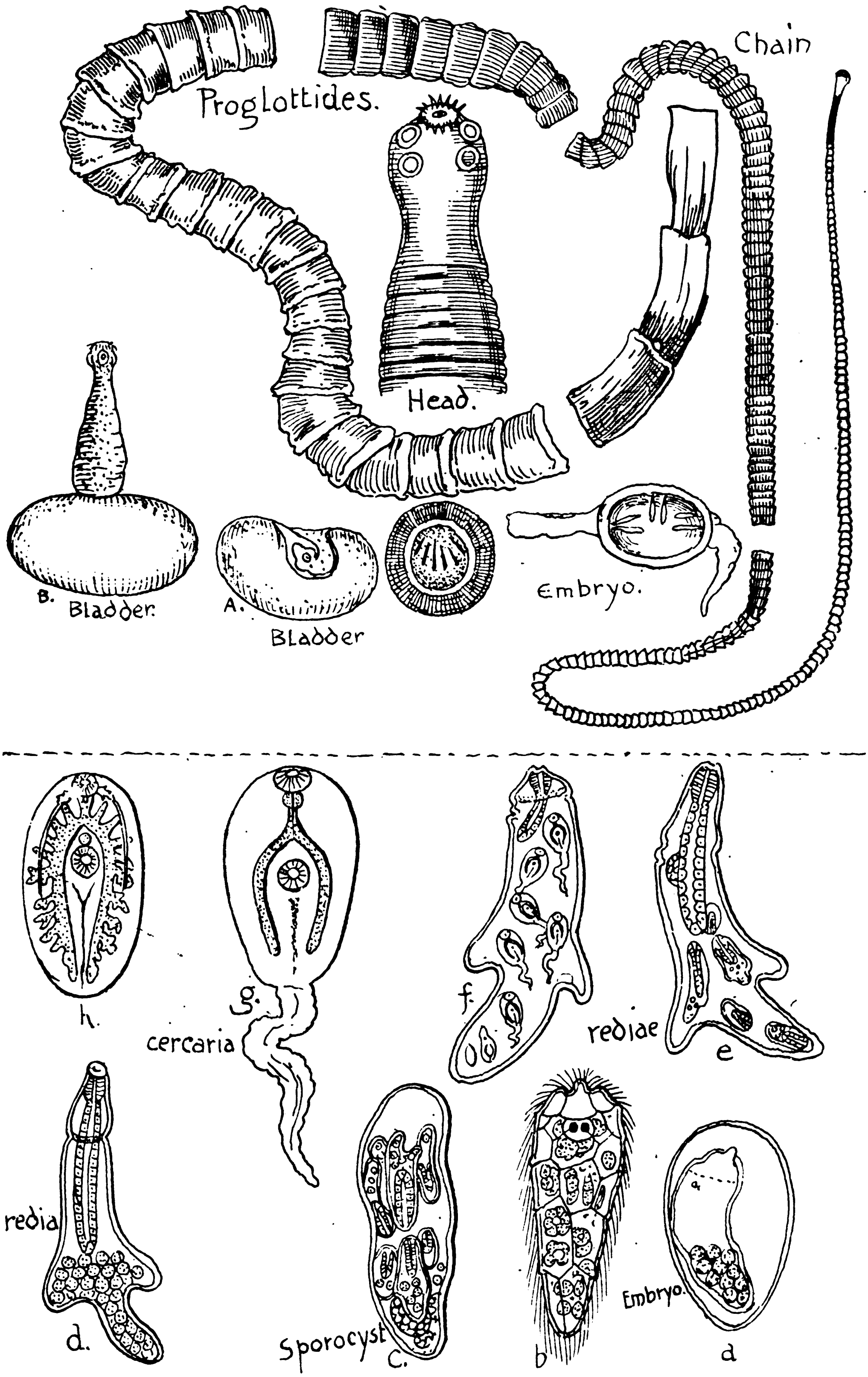
The upper half of the diagram shows the life-history of Tænia.

Begin with the six-hooked embryo within its egg-shell. It becomes a bladder-worm or proscolex, first (*A*) with inverted, and then (*B*) with everted "head" or scolex.

The "head" is shown enlarged; the suckers and hooks and the first joints are obvious.

Fragments of a complete tapeworm are also depicted, showing the minute head, and the increasing size of the joints or proglottides.

Fluke and Tape-Worm.



their life in some Invertebrate. The relations of the class are on the one hand with the free-living Turbellarians, on the other hand with the parasitic Cestodes or tapeworms.

Type, *The Liver-Fluke* (*Fasciola* (*or Distomum*) *hepatica*).

The adult fluke lives in large numbers in the bile-duct of the sheep. It also occurs in other domestic animals, and rarely in man. In the sheep it causes the serious disease called liver-rot. It is flat, oval, and leaf-like, measures about an inch in length by half an inch across the broadest part, varies from reddish brown to grayish yellow in colour. As the word *Distomum* suggests, there are two suckers,—an anterior, perforated by the mouth; a second, imperforate, a little further back on the mid-ventral line.

There is a muscular pharynx and a blind alimentary canal which sends branches throughout the body. The nervous system consists of a ganglionated collar round the pharynx, from which nerves go forward and backward; of these, the two which run laterally are most important. Although the larva has at first two eye-spots, there are no sense-organs in the adult. The body-cavity is represented only by a few small spaces. Into these there open the ciliated ends of much branched excretory tubes, which unite posteriorly, and communicate with the exterior by a terminal pore. The reproductive system is hermaphrodite and complex. From much branched testes, spermatozoa pass by a pair of ducts (vasa deferentia) into a seminal vesicle lying in front of the ventral sucker. Thence they are expelled by an ejaculatory duct, which passes through a muscular protrusible penis. The retracted penis and the seminal vesicle lie in a space or "cirrus sac" between the ventral sucker and the external male genital aperture. The ovary also is branched, but less so than the testes. From its tubes ova are collected into an ovarian duct. Nutritive cells are gathered from very diffuse yolk glands, collected in a reservoir, and pass by a duct into the end of the aforesaid ovarian duct. At the junction of the yolk-duct and the ovarian duct there is a shell-gland, which secretes the "horny" shells of the eggs, and from near the junction, a fine canal (the Laurer-Stieda

canal) seems to pass direct to the exterior, opening on the dorsal surface. The meaning of this is still somewhat uncertain. In some cases it is said to be a copulatory duct; in others it is regarded as a safety valve for overflowing products. From the junction of the ovarian duct and the duct from the yolk reservoir, the eggs (now furnished with yolk cells, accompanied by spermatozoa, and encased in shells) pass into a wide convoluted median tube, the oviduct or uterus, which opens to the exterior at the base of the penis. Self-fertilisation is probably normal, but in some related forms cross-fertilisation has been observed.

Life-History.—The fertilised and segmented eggs pass in large numbers from the bile-duct of the sheep to the intestine, and thence to the exterior. A single fluke may produce towards half a million embryos, which illustrates the prolific reproduction often associated with the luxurious conditions of parasitism, and almost essential to the continuance of species whose life-cycles are full of risks. Outside of the host, but still within the egg-case, the embryo develops for two or three weeks, and eventually escapes at one end of the shell. Those which are not deposited in or beside pools of water must die. The free embryo is conical in form, covered with cilia, provided with two eye-spots, and is actively locomotor. By means of its cilia it swims actively in the water for some hours, but its sole chance of life seems to depend on meeting a small amphibious water-snail (*Limnæus truncatulus*), into which it bores its way. Within the snail, *e.g.*, in the pulmonary chamber, the embryo becomes passive, loses its cilia, increases in size, and becomes a long sac or *sporocyst.* Sometimes the sporocyst divides transversely, but as this is rare, we may leave it out of account.

Within the sporocyst certain cells behave like parthenogenetic ova. Each segments into a ball of cells or morula, which is invaginated into a gastrula, and grows into another form of larva—the *redia.* These rediæ burst out of the sporocyst, and migrate into the liver or some other organ, killing the snail if they are very numerous. Each redia is a cylindrical organism with a short alimentary canal.

Like the sporocysts, the rediæ give rise internally to more embryos, of which some are simply rediæ over again, while the last set are quite different,—long-tailed *cercariæ*, with

two suckers and a forked food-canal. These emerge from the rediæ, wriggle out of the snail, pass into the water, and moor themselves to stems of damp grass. There they lose their tails and become encysted. If the encysted cercaria on the grass stem be eaten by a sheep, it grows, in about six weeks, into the adult sexual fluke.

To recapitulate, the developing embryo becomes a free-swimming form, which bores into a snail, and changes into a sporocyst.

From certain cells of the sporocyst rediæ are developed, and these may similarly give rise to other rediæ.

Eventually, within the rediæ the tailed cercariæ are formed, and these in favouring circumstances grow into the adult flukes.

The above history has been independently worked out by Leuckart and Thomas.

It will be noted that the sporocyst is the modified embryo, but that it has the power of giving rise asexually to rediæ. These develop, however, from special cells of the sporocyst which we may compare to precociously developed parthenogenetic ova. Though the reproduction is asexual, it is not comparable to budding or division. The same power is possessed by the rediæ, and there are thus several (at least two) asexual generations between the embryo and the adult. Finally, it must be clearly understood that the cercaria is the young fluke.

The disease of liver-rot in sheep is common and disastrous. It has been known to destroy a million sheep in one year in Britain alone. It is especially common after wet seasons, and in damp districts. The preventives suggested are drainage of pastures and dressings of lime and salt; destruction of the eggs, the snails, infected manure, and diseased sheep. It is usual to give the infected sheep some salt and a little dry food.

Classification.

Trematodes with direct development—Monogenetic.

e.g., *Polystomum integerrimum.* This form with many suckers will be found in the bladder of the frog. It attaches itself in its youth to the gills of tadpoles, passes thence through the food-canal to the bladder, where it develops slowly for years.

Gyrodactylus, found on the gills and fins of fresh-water

fishes. It is viviparous, but the embryo, before it is extruded, itself contains an embryo, and this in turn another, so that three generations of embryos are represented simultaneously.

Diplozoon paradoxum, consists of two individuals united. The single embryo (*Diporpa*) is at first free-swimming, but becomes a parasite on the gills of the minnow, and there two individuals unite very closely and permanently.

Tristomum, with three suckers, is not uncommon on the skin of some marine fishes.

Trematodes with indirect development—Digenetic.

e.g., *Fasciola* or *Distomum*.

Bilharzia or *Gynæcophorus hæmatobius*, a dangerous parasite of man, widely distributed in Africa. It infests the urinary and visceral blood-vessels. The sexes are separate, and the male carries the female inserted in a groove.

Monostomum, a form with one sucker.

Class CESTODA. Tapeworms, etc.

The Cestodes are elongated flat worms, endoparasitic in adult life. With one exception the adults occur in the alimentary canal of Vertebrates.

In the simpler forms (*Archigetes*, *Caryophyllæus*, *Amphilina*), the body consists of one joint, and has but one set of (hermaphrodite) reproductive organs. In median types (*e.g.*, *Ligula*), there are several sets of reproductive organs and hints of jointing. In the more familiar forms, such as *Tænia* and *Bothriocephalus*, there are numerous joints, each with a measure of independence, each with a full set of reproductive organs.

An ordinary tapeworm stands in a certain sense between unsegmented and segmented "worms," for while it has numerous similar joints, these are not integrated into a unified many-jointed organism.

The life-history is markedly divided into non-sexual and sexual stages, which, though not accurately comparable to "alternation of generations," illustrate the same general rhythm.

Begin with a long tapeworm, pendent by its "head" from the wall of the intestine. We may take the case of *Tænia solium*, one of the most frequent tapeworms infesting man. The fixed "head," with four suckers and many hooks, has

budded off a long chain of joints. The last of the joints or *proglottides*, is liberated (singly or along with others) and passes down the intestine of its host to the exterior. It has some power of muscular contraction, and is distended with little embryos within firm egg-shells. When the proglottis ruptures, these cases are set free.

In certain circumstances, the embryos, within their firmly resistent egg-shells, may be swallowed by the omnivorous pig. Within the alimentary canal of this animal the egg-shells are dissolved, and the embryos bearing six anterior hooks are liberated. They bore their way from the intestine into the muscles or other structures, and there encyst. They increase in size and become passive, vegetative, asexual "bladderworms." A bud from the wall of the bladder or *proscolex* grows into the cavity of the same, and forms the future "head" or *scolex*. It is afterwards everted, and then the bladderworm consists of a small head attached by a short neck to a relatively large bladder. But this remains quiescent, and without power of further development, unless the pig be eaten by some other Vertebrate.

When man unwittingly eats "measly" pork, that is pork infested with bladderworms, an opportunity for further development is afforded. The bladder is lost, and is of no importance, but the "head" or scolex fixes itself to the wall of the intestine. There it is copiously and richly nourished, and buds off asexually a chain of joints.

As these joints are pushed by younger interpolated buds further and further from the head, they become sexually mature, developing complex hermaphrodite reproductive organs. The ova produced in these are fertilised, apparently by spermatozoa from the same joints; the proglottis becomes distended with ripe eggs and developing embryos. These ripe joints are liberated, and the vicious circle may recommence. Happily, however, the chances are millions to one against the embryo becoming an adult.

The above history is true *mutatis mutandis* for many other tapeworms. It will be observed that the embryo grows into a *proscolex* or bladder, which buds off a *scolex* or head, which, in another host, buds off the chain of *proglottides*, but as it is virtually the same animal throughout, it is not accurate to say that the life-history includes an "alternation

of generations." It is doubtful, however, what term should be applied to those cases in which the bladderworm (*Cœnurus* and *Echinococcus*), forms not one head only but many, each of which is capable of becoming an adult tapeworm. The only known exception to the fact that sexual tapeworms are parasites of Vertebrates, is *Archigetes Sieboldii*, a simple cestode which is sexual within the small fresh-water worm *Tubifex rivulorum*.

General Characters.—With the conditions of endoparasitic life, we may associate the occurrence of fixing-organs (suckers, and usually hooks as well), the absence of sense-organs, the low though somewhat complex nervous system (lateral nerve-cords and anterior ganglionated commissures), the entire absence of a food-canal, the absorption of food through the skin, and finally, the prolific multiplication.

The body-cavity is represented only by spaces. The excretory system consists of fine branches ending with ciliated funnels in the above-mentioned spaces, and connected with larger longitudinal vessels which have transverse bridges at each joint and a terminal pore.

The male reproductive organs include diffuse testes, a vas deferens, and a protrusible terminal cirrus. The female organs include a pair of ovaries, yolk-glands, a shell-gland, a receptacle for storing spermatozoa, a uterus in which the eggs develop, and a vagina by which spermatozoa enter. Self-impregnation is at least a common occurrence. In the ripe joint the distended uterus occupies almost the whole space.

Some Important Forms.

Adult or Tapeworm Stage.	Bladderworm or Proscolex Stage.
Tænia solium, in man; the head bears four suckers and many hooks.	*Cysticercus cellulosæ*, in pig.
Tænia saginata or *mediocanellata*, in man; the head is hookless, with four suckers.	Bladderworm in ox.
Tænia echinococcus, in dog.	*Echinococcus veterinorum*, with many heads; in domestic animals, and sometimes in man.
Tænia cœnurus, in dog.	*Cœnurus cerebralis*, with many heads, in brain; etc., of sheep.
Tænia serrata, in dog.	*Cysticercus pisiformis*, in rabbit and hare.
Tænia cucumerina, in cat.	*Cysticercus fasciolaris*, in mouse.
Bothriocephalus latus, in man; without hooks and with two lateral suckers on head; the proglottides are less distinctly separate than those of *Tænia*.	Embryo is ciliated and free-swimming, becomes a parasite of pike and burbot.

The Cestodes are closely connected with Trematodes by such forms as *Amphilina*, *Caryophyllæus*, *Archigetes.* Zoologically, they are interesting on account of their life-histories, the degeneration associated with their parasitism, the prevalence of self-impregnation, and the complexity of the reproductive organs. Practically, they are of importance as parasites of man and domestic animals. The medical student should consult Leuckart's great work, *The Parasites of Man*, part of which has been translated by W. E. Hoyle (Edin. 1886).

SECOND SERIES OF "WORMS."

Class NEMERTINA. Nemerteans.

This class of worm-like animals is often included among the Plathelminthes, along with Turbellarians, Trematodes, and Cestodes. Like the Plathelminthes, Nemerteans are bilaterally symmetrical, unsegmented, and somewhat flat, but their deeper characteristics warrant us in giving them a separate position.

General Characteristics.

The Nemerteans, or ribbon-worms, are almost exclusively marine, and are common under stones at low tide. They are carnivorous in habit, and often very long and elastic, notably in the case of *Lineus*, of whose uncoiled length I have measured twelve feet. When captured or injured they readily break into parts, which can sometimes regenerate the whole body.

The animal tends to grow lank; the body is unsegmented, but there is sometimes an internal repetition of parts; the ectoderm is ciliated. A few swim, most creep slowly, partly by the movements of the cilia, partly by the muscular contractions of the body.

A well-developed straight or slightly pouched food-canal extends through the body, and there is virtually no body-cavity.

Above the food-canal, and independent of it, there lies within a definite sheath an eversible poisonous, and often spine-bearing, proboscis. It is surrounded by a nerve-ring from the brain, is probably both offensive and tactile, is sometimes nearly as long as the worm, and is thrown out at an anterior aperture usually situated above the mouth.

The nervous system consists of two cerebral ganglia and two lateral nerve-cords. In most forms the cords lie along the sides, but sometimes they approach one another ventrally, and in one or two cases dorsally. There is sometimes a supra-anal union of the lateral cords, and there is an anterior commissure around the proboscis. Simple eyes and other sensory structures are present. Very characteristic of Nemerteans are two ciliated slits on the sides of the head. They sometimes extend as far inwards as the brain, and have possibly a respiratory function, as their slight resemblance to gill-slits and the occurrence of hæmoglobin in the nerve-substance of many Nemerteans (Schizonemertea) suggest.

The Nemerteans seem to be the simplest animals with a distinct blood-vascular system. Its cavities represent the remnants of a cœlome. In some, the blood has distinct corpuscles; in *Drepanophorus*, these contain hæmoglobin. One would think that the evolution of a respiratory pigment so efficient as hæmoglobin would soon induce other steps of progress.

Excretory organs are represented by two anterior kidney-tubes or nephridia. The reproductive organs are very simple; the animals are almost all unisexual.

The development is often indirect, thus *Lineus* has a creeping ciliated larva (the larva of Desor), and a commoner free-swimming helmet-like type is known as a Pilidium.

Classification.

Order 1. Palæonemertea. The head is without deep lateral grooves. The proboscis is without spines. The mouth lies behind the brain.

e.g., *Carinella; Polia.*

Order 2. Schizonemertea. The head has a deep cleft on each side. The proboscis is without spines. The mouth lies behind the brain.

e.g., *Lineus*, some species of which attain great length; *Cerebratulus; Langia*, with nerve-cords which approach dorsally.

Order 3. Haplonemertea. The head is without deep lateral grooves. The proboscis is armed with a spine, or with several spines. The mouth is usually in front of the brain.

Amphiporus; Drepanophorus, with oval blood-corpuscles containing hæmoglobin, and nerve-cords which approach ventrally; *Nemertes.*

Order 4. Malacobdellini. The head is without lateral grooves. The proboscis is without spines. There is a sucking disc at the hind end of the body. The only genus is *Malacobdella*, which lives (probably) parasitically in sea-mussels.

Relationships.—Hubrecht maintains with considerable confidence that Nemerteans exhibit affinities with Vertebrates:—

Thus (1) The firm sheath of the proboscis is compared to the notochord;

(2) The ingrowth from in front of the mouth which forms the proboscis is compared to the oral part of the hypophysis or pituitary body;

(3) The ciliated slits on the head are compared to gill-slits;

(4) There is some plasticity in the arrangement of the two nerve-cords, for as they approach ventrally they tend to produce a ventral nerve-cord as in most segmented Invertebrates, while an approximation dorsally would result in a nerve-cord in the position characteristic of Vertebrates.

THIRD SERIES OF "WORMS"—NEMATHELMINTHES.

Class NEMATODA. Thread-worms and hair-worms.

The Nematodes include many parasites, *e.g*, the thread-worms of children, and the very dangerous *Trichina*, but many others spend a large part or even the whole of their life in fresh water or in damp earth. They are very hardy animals, able to live for many days with very little food or oxygen, and able to survive prolonged desiccation—in the case of some "paste eels" for fourteen years. Their food consists of the juices of their hosts, or of rotten organic stuff.

The body is unsegmented, usually cylindrical, and clad in a firm cuticle made by the epidermis. There is never any ciliated epithelium. The longitudinal muscles lie in four distinct groups, two on each side above and below.

A straight and simple food-canal usually lies in a distinct body-cavity, and consists of a muscular œsophagus sometimes with cuticular teeth, a mid-gut, and a short rectum. A few forms have no gut.

The nervous system consists of a collar round the gullet, with six nerves extending forward, and other six backward. One runs along the median-dorsal, another along the median-ventral line. Simple eyes are frequently present.

Along each side, between the dorsal and ventral groups of muscles, there is a narrow area, in which runs a thin-walled canal, perhaps excretory. It unites with the corresponding vessel of the other side, and opens anteriorly and ventrally. There is no blood-vascular system.

The sexes are separate; the male is the smaller; it often has copulatory spicules. The reproductive organs are long tubes, opening about the middle of the body in the females, posteriorly in the males. The spermatozoa are not tailed, but slightly amœboid.

The life-history is often complicated, and may exhibit alternation of generations.

Life-Histories.

1. The embryo grows directly into the adult, and both live in fresh or salt water, damp earth, or rotting plants—Enoplidæ, *e.g.*, *Enoplus*, and other members of the family.

2. The larvæ are free in the earth, the sexual adults are parasitic in plants, or in Vertebrate animals; *e.g.*, *Tylenchus scandens*, a common parasite on cereals; *Strongylus* and *Dochmius* in man.

3. The sexual adults are free, the larvæ are parasitic in insects; *e.g.*, *Mermis*. The fertilised females of *Sphærularia bombi* pass from the earth into the body-cavity of humble-bee and wasp, whence their larvæ bore into the intestine and eventually emerge.

4. The larvæ are parasitic in one animal, the sexual adults in another which feeds on the first. Thus *Ollulanus* passes from mouse to cat, *Cucullanus* from *Cyclops* to perch.

There are other life-histories, and many degrees of parasitism. The most remarkable form is *Angiostomum* (or *Ascaris*, or *Leptodera*) *nigrovenosum*. In damp earth males and females occur, the progeny of which pass into the lungs of frogs and toads. There they mature into hermaphrodite animals (the only instance among Nematodes), which produce first spermatozoa and then ova. They are self-impregnating, and the young pass out into the earth as males or females. In this case there is alternation of generations, and a somewhat similar story might be told of *Rhabdonema strongyloides* from the intestine of man, and *Leptodera appendiculata* from the snail.

There are several quaint reproductive abnormalities; thus—the female *Sphærularia bombi*, which gets into the body-cavity of the humble-bee, has a prolapsed uterus, larger than the body; the male of *Trichodes crassicauda* passes into the uterus of the female.

Parasitic in Man.

Name.	Position.	History.	Result on Host.
Ascaris lumbricoides (common).	Small intestine.	Probably enter the body as larvæ, along with vegetable food or impure water.*	Rarely dangerous, but may perforate intestine, and cause abscesses.
Oxyuris vermicularis (common).	From stomach to rectum, mostly in cæcum.	,,	Rarely more than discomfort.
Trichocephalus dispar (common).	Cæcum and colon.	,,	,,
Dochmius (*Anchylostoma*) *duodenalis* (Europe, Egypt, Brazil). *Rhabdonema strongyloides.*	Small intestine. Associated with *Dochmius*.	The larvæ seem to live freely in the earth.	Dangerous anæmia.
Filaria sanguinis hominis (Australia, China, India, Egypt, and Brazil).	Mature female in lymphatic glands, embryos in blood.	Larvæ in a Mosquito.	Elephantiasis, and hæmaturia.
Dracunculus (*Filaria*) *medinensis* (Guineaworm) in Arabia, Egypt, Abyssinia, etc.	The female is 1–6 feet long, encysts beneath skin. The male is not known, though his tail is said to have been seen.	Larvæ in a *Cyclops*.	Skin abscesses.
Trichina spiralis.	Becomes sexually mature in the intestine; embryos, produced rapidly and viviparously, bore their way to muscles, and become encysted.	Occurs among rats, probably passes thence to pigs, and from diseased pig's muscle to man.	Inflammatory processes, often fatal, are brought about by the migration of the young worms from intestine to muscles.

Classification.

At present the Nematodes are usually classified in families—Ascaridæ, Anguillulidæ, etc. With these we need not concern ourselves here, but it is important to notice that the Gordiidæ (*e.g.*, *Gordius aquaticus*—the horse-hair-worm) are very different from all the others. In the adult the mouth is shut and the food-canal is partly degenerate. The adults live freely in fresh-water; the larvæ occur in water insects, or in animals (fish, frog, etc.) which eat these.

* Von Linstow believes that *Julus guttulatus* is the intermediate host.

Class ACANTHOCEPHALA.

For a single genus *Echinorhynchus*, whose larvæ live in Arthropods, and the adults in Vertebrates, a special class, ACANTHOCEPHALA, has been established. We may provisionally place this genus, which has about a hundred species, beside Nematodes, but the relationship does not seem to be very close. Mouth and gut are absent. The anterior end bears a protrusible hooked proboscis.

Echinorhynchus proteus of Pike, larva in the Amphipod *Gammarus pulex*.
,, *angustatus* of Perch, larva in the Isopod *Asellus aquaticus*.
,, *gigas* of Pig, larva in young Cockchafers.

FOURTH SERIES OF "WORMS"—ANNELIDS.

In the earthworm, and in the common marine Nereids, we at once recognise that the body is divided into a series of rings. But these are not merely external markings, they represent genuine segments or somites of the body. For each segment there is usually a pair of ganglia on the ventral nerve-cord, and a pair of excretory nephridia.

We begin with the bristle-footed worms (Chætopoda), with the familiar earthworm and the marine lob-worm as types. To these must be added certain remarkably larval worms, which probably deserve their name of Archi-Annelids. Very different are the degenerate parasitic Myzostomata which form galls on Crinoids. Divergent but yet with the essential Annelid features are the leeches (Discophora). Finally, some zoologists provisionally include *Sagitta* in this series as an Annelid with three segments, and also the Rotifers, since they somewhat resemble the larvæ of Annelids.

Series of Annelids.

Class CHÆTOPODA. Worms with bristles.
Oligochæta, *e.g.*, Earthworm.
Polychæta. Marine Worms.
Echiuridæ, *e.g.*, *Echiurus*, *Bonellia*.

To the class of Chætopods are appended—
(1) The primitive Archi-Annelida.
(2) The parasitic Myzostomata.

Class DISCOPHORA OR HIRUDINEA. (Leeches.)
To the Annelid series are appended two classes—
Chætognatha or Arrow-Worms, *e.g.*, *Sagitta*.
Rotatoria or Rotifers.

Class CHÆTOPODA. Bristly Worms.

Segmented animals with setæ developed in little skin-sacs, either on a uniform body-wall or on special locomotor protrusions known as parapodia. The segments indicated externally by rings, are often marked internally by partitions running across the body-cavity, which is usually well-developed. The nervous system generally consists of a double ventral chain of ganglia, connected with a pair of dorsal or cerebral centres, by means of a ring round the beginning of the gut. Two excretory tubes or nephridia are typically present in each segment, and they or their modifications may also function as reproductive ducts. The reproductive elements are formed on the lining membrane of the body-cavity, and the development is either direct or with a metamorphosis.

The two prominent divisions of this class may be contrasted as follows:—

OLIGOCHÆTA, *e.g.*, Earthworm.	POLYCHÆTA, *e.g.*, *Nereis*.
With no parapodia, and with few setæ.	With parapodia and with numerous setæ.
Other external appendages are also wanting.	With antennæ, gills, and cirri.
Hermaphrodite.	Sexes usually separate.
Development direct.	A metamorphosis in development.
Living in fresh water or in the soil.	Marine.

TYPE OF OLIGOCHÆTA.—The Earthworm (*Lumbricus*).

Earthworms eat their way through the ground, and form definite burrows, which they often make more comfortable by a lining of leaves. The earth swallowed by the burrowers is reduced to powder in the gut, and, robbed of some of its decaying vegetable matter, is discharged on the surface as the familiar "worm-castings." By the burrowing, the earth is loosened, and ways are opened for plant-roots

and rain drops; the internal bruising reduces mineral matter to more useful form; while, in burying the surface with earth brought up from beneath, the earthworms have been ploughers before the plough. Darwin calculated that there were on an average over 53,000 earthworms in an acre of arable ground, that ten tons of soil per acre pass annually through their bodies, and that they cover the surface with earth at the rate of three inches in fifteen years. He was therefore led to the conclusion, that earthworms have been the great soil-makers, or more precisely, that the formation of vegetable mould was mainly to be placed to their credit. According to Gilbert White (1777), "the earth without worms would soon become cold, hard bound, void of fermentation, and consequently sterile;" while Darwin (1881) said that "it may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly-organised creatures."

Though without eyes, earthworms are sensitive to light and persistently avoid it, remaining underground during the day unless rain floods their burrows, and reserving their public life for the night. Then, prompted by "love" and hunger, they roam about on the surface, leaving on the moist roadway the trails which we see in the morning. More cautiously, however, they often remain with their tails fixed in their holes, while with the rest of their body they move slowly round and round. The nocturnal peregrinations, the labour of eating and burrowing, the transport of leaves to their holes, the collection of little stones to protect the entrance to the burrows, include most of the activities of earthworms, except as regards pairing and egg-laying, of which something will afterwards be said. As digging is not yet quite archaic, it may be noticed that when an earthworm is halved with the spade it does not necessarily die, for the head-portion may grow a new tail, while a decapitated worm has even been known to grow a new head and brain. The principal enemies of the earthworm are moles and birds, while the male reproductive organs are always infested by unicellular parasites—Gregarines of the genus *Monocystis*, and little threadworms seem almost always to occur in the excretory tubes.

Form and External Characters.—The earthworm is often

about six inches long, with a pointed head end, and a cylindrical body rather flattened posteriorly. The successive rings seen on the surface mark true segments. The mouth is over-arched by the most anterior (pre-oral) segment, while the food-canal terminates at the blunt posterior end. The skin is covered by a thin transparent cuticle, traversed by two sets of fine lines which break up the light and produce a slight iridescence. On a region extending from the 31st to the 38th ring, the skin of mature worms is swollen and glandular, forming the clitellum or saddle, which helps the worms as they unite in pairs, and forms the slimy stuff which hardens into cocoons for the eggs. The middle line of the back is marked by a special redness of the skin. On the sides and ventral surface, we feel and see four rows of tiny bristles or setæ, which project from little sacs, are worked by muscles, and assist in locomotion. These bristles are fixed like pins into the ground, at times so firmly that even a bird finds it difficult to pull the worm from its hole. As each of the four longitudinal rows is double, there are obviously eight bristles to each ring. On the skin of the ventral surface, there are not a few special apertures, which should be looked for on a full-grown worm, but careful examination of several specimens is usually necessary. Almost always plain on the 15th ring are the two swollen lips of the male ducts, less distinct on the 14th are the apertures of the oviducts through which the eggs pass, while on each side between segments 9 and 10, 10 and 11, are the openings of two sperm-reservoirs or spermathecæ into which male elements from another earthworm pass, and from which they again pass out to fertilise the eggs of the earthworm when these are laid. Each segment contains a pair of excretory tubes, which have minute ventral-lateral apertures, while on the middle line of the back between every two adjacent rings there are minute pores, through which fluid from the body-cavity may exude.

Skin and Bristles.—Outermost lies the thin cuticle, a smooth shred of which should be mounted on a slide and examined under high power, to see the intersecting lines which produce interference of light and iridescence. Like any other cuticle, it is produced by the cells which lie beneath, and it is perforated by the apertures previously mentioned. The epidermis clothing the worm is a single

layer of cells, of which many are glandular, especially in the region of the saddle. In a few species the skin is slightly phosphorescent. The bristles, which are longest on the genital segments, are much curved, and lie in small sacs of the skin, in which they can be replaced after breakage.

Muscular System.—The earthworm moves by the contraction of muscle cells, which are arranged in hoops underneath the skin, and in longitudinal bands more internally. The special muscles about the mouth and pharynx have considerable powers of grasping, while less obvious muscular elements occur in the wall of the gut, in the partitions which run internally between the segments, and on the outermost portions of the excretory tubes.

The Body-Cavity.—Unlike the leech, the earthworm has a very distinct body-cavity, down the middle of which the gut extends, and across which run the partitions or septa incompletely separating successive segments. In this cavity, there is some fluid with cellular elements, of which the most important are yellow cells detached from the walls of the gut. Possible communications with the exterior are by the dorsal pores, and also by the excretory tubes which open internally into the cavities of the segments.

The Nervous System.—Along the middle ventral line lies a chain of nerve-centres or ganglia, really double from first to last, but compactly united into what to unaided eyes seems a single cord. As the segments are very short, the limits of the successive pairs of ganglia are not very evident, especially in the anterior region, but they are plain enough on a small portion of the cord examined with the microscope, when it may also be seen that each of the pairs of ganglia gives off nerves to the walls of the body. Anteriorly, just behind the mouth, the halves of the cord diverge and ascend, forming a ring around the pharynx. They unite above in two dorsal or cerebral ganglia. These form the earthworm's "brain," and give off nerves to the adjacent pre-oral segment or prostomium, on which are numerous sensitive cells. These coming in contact with many things doubtless receive impressions, which are transmitted by the associated nerves to the "brain." As Mr Darwin observed that earthworms seized hold of leaves in the most expeditious fashion, taking the sharp twin leaves of the Scotch fir by their

united base, we may credit the earthworms with some power of profiting by experience; moreover, as they deal deftly with leaves of which they have no previous experience, we may even charitably grant them a modicum of intelligence. From the nerve-collar uniting the dorsal ganglia with the first pair on the ventral cord, nerves are given off to the pharynx or gut, forming what is called a "visceral system." The earthworm has no special sense-organs, but we have just mentioned sensitive cells, which are particularly abundant on the head end of the worm. By them the animal is made aware of the differences between light and darkness, and of the approaching tread of human feet, not to speak of the hostile advances of a hungry blackbird. The sense of smell is also developed.

Two facts in regard to minute structure deserve attention. The nerve-cells, instead of being confined to special centres or ganglia, as they are in Arthropods, occur diffusely along with the nerve-fibres throughout the course of the cord. Along the dorsal surface of the ventral nerve-cord there run three peculiar tubular fibres, with firm walls and clear contents. These "giant fibres," which do not seem to be nervous, but are rather supporting elements, have been dignified by the name of neurochord, and ingeniously compared with the notochord of Vertebrates.

Alimentary System.—Earthworms eat the soil for the sake of the plant débris which it may contain, and also, indeed, because they must swallow as they tunnel. In eating they are greatly helped by the muscular nature of the pharynx, whence the soil passes down the gullet or œsophagus, first into a swollen crop, then into a strong-walled grinding gizzard, and finally along a long digestive and absorptive stomach-intestine. On the gullet are three pairs of œsophageal or calciferous glands—the products of which are limy and able to affect the food chemically, probably counteracting the acidity of the decaying vegetable matter. The long intestine has its internal surface increased by a dorsal fold, which projects inwards along the whole length. In this fold, and all over the outer surface of the gut, yellow-cells are thickly crowded. There is no warrant for calling these hepatic or digestive. Structurally they are pigmented cells of the peritoneal epithelium, which here, as in most other

animals, lines the body-cavity and the outside of the gut. As to their function we know that they absorb particles from the intestine, and go free into the body-cavity, whence, as they break up, their débris may pass out by the excretory tubes. When a worm has been made to eat powdered carmine, the passage of these useless particles from gut to yellow-cells, from yellow-cells to body-cavity, and thence out by the excretory tubes, has been traced. Various ferments have been detected in the gut, a diastatic ferment turning the starchy food into sugars, and others—peptic and tryptic—even more important. The wall of the stomach-intestine from without inwards, as may be traced in sections, is made up of pigmented peritoneum, muscles, capillaries, and an internal ciliated epithelium. In the other parts of the gut the innermost lining is not ciliated, but covered with a cuticle.

Vascular System.—The fluid of the blood is coloured red with hæmoglobin, and contains small corpuscles. Along the median dorsal line of the gut a prominent blood-vessel extends, another (supra-neural) runs along the upper surface of the nerve-cord, another (infra-neural) along the under surface, while two small lateral-neurals pass along each side of this same cord. All these longitudinal vessels, of which the first three are most important, are parallel with one another; the first three meet in an anterior network on the pharynx; the dorsal and the supra-neural are linked together in the region of the gullet by five or six pairs of pulsatile vessels or "hearts." The precise path of the blood is not known, but the distribution of vessels to skin, nephridia, and alimentary canal is readily seen.

Respiration is effected by the distribution of blood on the general surface of the skin.

Excretory System.—When a worm is fed with carmine particles, these may be taken up from the intestine by the yellow cells, which may pass them into the body-cavity. Finally, the particles have been seen passing out by the excretory tubes. There is a pair of these little kidneys, nephridia or segmental organs, in each segment except the first four. Each opens internally into the segment in front of that on which its other end opens to the exterior. They remove little particles from the body-cavity, but

probably get finer waste-products from the associated blood-vessels. Nephridia occur in many animals, in most young Vertebrates as well as among Invertebrates, but they are never seen more clearly than in the earthworm. When a nephridium is carefully removed, along with a part of the segment septum through which it passes, and examined under the microscope, the following three parts are to be seen :—(*a*) an internal ciliated funnel, (*b*) a trebly coiled ciliated tube, at first transparent then glandular and granular, and (*c*) a muscular duct opening to the exterior. Minute particles swept into the ciliated funnel pass down the ciliated coils of the tube, and out by the muscular part which opens just outside of the ventral bristles. The coiled tube consists in part at least of a series of intra-cellular cavities, that is to say, it runs through the middle of the cells which compose it ; the external muscular portion arises from an invagination of skin. The nephridia usually lodge minute parasitic Nematodes.

Reproductive System.—The earthworm is hermaphrodite, and its reproductive organs are somewhat difficult to demonstrate with completeness. To see them it will be necessary to dissect several earthworms with special attention to the several parts.

(*a*) *The Male Organs* consist of a pair of testes, three pairs of seminal vesicles, and a paired vas deferens.

(1) The testes lie near the nerve-cord on the septa between segments 10 and 11 ; each is "a white translucent body of irregular quadrangular form, rarely more than one-tenth of an inch in diameter." They will not be found by the busy student.

(2) Mother-sperm-cells, which give rise by division to young spermatozoa, pass from the testes to the much lobed seminal vesicles, where the spermatozoa are matured. These seminal vesicles are very prominent, and seem to be outgrowths of the septa between segments nine to twelve. Among the spermatozoa there are parasitic Gregarines (*Monocystis*) in various stages of development.

(3) The spermatozoa pass from the seminal vesicles into two vasa deferentia or male ducts. These open to the exterior on the 15th segment. Each vas deferens bears

two ciliated funnels, which collect spermatozoa in segments 10 and 11, and soon unite in one duct.

(*b*) *The Female Organs* consist of two ovaries, and two oviducts each of which has a side receptacle for the eggs.

(1) The two ovaries are small bodies situated near the nerve-cord on the septum between segments 12–13. Each is pear-shaped, the stalk of the pear being a string of ripe ova. They are more likely to be seen than the testes.

(2) The two oviducts open internally on the anterior face of the septum between 13–14, and externally on the ventral surface of segment 14. Into the wide ciliated internal mouths, which lie opposite the ovaries, the ripe eggs pass.

(3) The egg-sac or receptaculum ovorum, near the internal mouth of each oviduct, is a posterior diverticulum of the septum between segments 13–14. Within it a few mature ova are stored.

(*c*) Two pairs of spermathecæ receive spermatozoa from *another* earthworm, and liberate them so that they fertilise the eggs of this one. They are white globular sacs, opening in the grooves between segments 9–10 and 10–11. According to some, these spermathecæ not only receive and store spermatozoa, but make them into packets or spermatophores. Others say that the glands of the clitellum make these packets. At any rate minute thread-like packets of spermatozoa are formed, and a pair of them may often be seen adhering to the skin of the earthworm about the saddle region.

When two worms unite sexually they lie apposed in opposite directions, the head of the one towards the tail of the other. What happens is that spermatozoa of the one pass into the spermathecæ of the other.

When the eggs of an earthworm are liberated they are surrounded by a sheath of gelatinous stuff secreted by the saddle. As this is peeled off towards the head a spermatophore is also enclosed. The packet bursts in the egg-capsule, and there fertilisation at length occurs.

Development of the Earthworm.

The various species of *Lumbricus* deposit their ova within cocoons, the substance for which is secreted by the saddle.

They make many cocoons about the same time, and each contains numerous ova, and also packets of sperms, so that fertilisation takes place outside the body. These cocoons are buried in the earth a few inches below the surface. They measure about a quarter of an inch in length.

The favourite time for egg-laying is during the spring and summer, though it may be continued throughout the whole year. The earthworm of the dung heap (*L. fœtidus*) makes this a habit, induced probably by the warmth of its habitat.

Of the many ova of the earthworm *L. terrestris*, only one comes to maturity, while of *L. fœtidus* a few, and of *L. communis* two may do so. But in the last species the two embryos are often twins formed from one ovum, separation taking place at the gastrula stage.

The whole process of growth, until leaving the egg, lasts from two to three weeks, the time varying however with the temperature.

The ovum is surrounded by a vitelline membrane, and is laden with yolk granules. It seems that several polar cells are formed, probably by division of the two primary ones separated from the ovum. Segmentation is rather unequal, and periods of rest alternate with periods of rapid division. Even the first cleavage divides the egg-cell unequally, the second divides the smaller part equally, and seems to cut off a small cell from the larger part. A resting stage now occurs, after which the division becomes more and more irregular, individual ova also presenting special peculiarities. During division an opening called a cleavage pore often occurs between the cells.

In about twenty-four hours, a nearly spherical, one-layered blastosphere or blastula is formed. It consists of only about thirteen cells. During the next twenty-four hours the cells increase in number rapidly, but the blastula remains one-layered. Two cells lying together do not take part in this division; they are rather larger than the rest, and their inner ends project into the cavity and are soon cut off. Gradually these large cells begin to sink in, giving rise to more daughter cells, and at last are quite included in the cavity. Thus there arise two parallel rows of cells within the blastula, and these define the longitudinal axis of the embryo. This is the beginning of the mesoblast which will

form all the muscles of the trunk, and which thus takes origin from two primary mesoblasts.

After five to six pairs of secondary mesoblasts have been formed, the blastula begins to flatten, and to elongate, becoming an oval disc. The cells of the lower surface become clearer, and the hypoblast is thus defined. The cells of the upper surface are smaller, and become very much flattened; they compose the epiblast. The mesoblasts lie side by side near one end, forming two rows extending forwards and downwards, but divergent, because of the flattening of the blastula. The hypoblast now becomes concave, and thus the blastopore arises, occupying the whole of the lower surface. The sides close in and the blastopore becomes a slit, which further closes from behind forwards leaving only a small opening,—the future mouth. During these processes the cells at the anterior tip of the blastopore, which will give rise to the præoral lobe, undergo no change, but the mesoblast has been active.

As gastrulation proceeds, the mesoblast rows grow forwards and upwards until they come near each other above the anterior tip of the blastopore, while their middle portions are carried downwards until they lie on the ventral surface. Over them the epiblast is thickened in two bands. Two longitudinal rows of epiblast cells near the anterior end, and ending behind in large cells, sink in just as the primary mesoblasts did. The thickening now extends ventrally until the two bands meet, and passing into the blastopore forms the stomatodæum. Even before this the embryo has begun to swallow the albumen in which it floats.

There are now two lateral bands of cells called the germ bands, composed of three layers: outside is the thickened epiblast, next, the rows of cells which sank in, and inmost the mesoblast rows. The mesoblast rows have met in the middle line by dividing and widening out into a pair of flattened plates, but they still end behind in the two primary mesoblasts. Cœlomic cavities develop in the plates, and the anterior ends meet above the mouth. The epiblastic rows which sank in (there were eight of them, four on each side of the median line, and each ending in a large mother cell) go on growing. The mother cells are apparently carried backwards as the embryo lengthens, leaving a trail of

daughter cells behind them. The cells so formed also divide, the embryo rapidly lengthening and finally becoming vermiform. The two inner rows (neuroblasts) give rise to the nervous system, the next two rows on either side (nephridioblasts) form parts of the nephridia, while of the fourth row nothing definite is known. Each row, ending behind in a single cell, widens out and deepens as it is traced forwards, the neuroblasts are much further forwards than the mesoblasts, with the nephridioblasts just behind them. The neural and mesoblastic rows can be traced round the mouth and help to form the prostomium, the others fade away at the sides of the stomatodæum. The mesoblast rows grow to meet one another on the median dorsal line.

Let us sum up this complex history :—

Fertilised ovum. | Blastosphere or blastula. | Two-layered gastrula with primitive mesoblasts.

- Epiblast or Ectoderm
  - (*a*) The original outer layer becomes the epidermis.
  - (*b*) The secondary inner stratum consists of two rows of neuroblasts which form the nervous system, and of four rows of nephridioblasts which form parts of the nephridia
- Mesoblast or Mesoderm formed from the division of the primitive 'mesoblasts.'
  - Muscle.
  - Blood-vessels.
  - Inner parts of nephridia.
  - Reproductive organs.
- Hypoblast or Endoderm.
  - Lining of mid-gut.

General Development of the Organs.—Though it will involve a slight repetition, we shall now describe the origin of the various organs.

The *skin* arises from the original outer wall of the gastrula. The "setigerous glands," within which the *setæ* develop, and from which they push their way to the exterior, arise partly from the rows of cells started by the nephridioblasts, and partly in all probability from the outermost of the four cell-rows previously mentioned. The double ventral *nerve-cord* is likewise ectodermic, though somewhat indirectly so, arising as it does from the neuroblasts. The two *cerebral ganglia*

DIAGRAM VIII.

THE EARTHWORM.

The figure named *Sect.* shows a transverse section of the earthworm; *cut.* the cuticle, *epid.* the epidermis, *circ. m.* the circular muscles, *long. m.* the longitudinal muscles, *b. c.* the body-cavity, *n.* the nerve-cord, *gut.* the gut, *fold.* its infolded dorsal ridge, *nephr.* a nephridium, *d. b. v.* the dorsal blood-vessel, *v. b. m.* the ventral or supra-neural blood-vessel, the infra-neural and the lateral-neurals are seen beside the nerve-cord, *s.* the setæ. (Partly after Lang.)

The figure named *Repr.* shows the reproductive organs; *t.* the testes, *s. v.* the seminal vesicles, *v. d.* the vas deferens with seminal funnels (*s. f.*), *ov.* the ovaries, *ovid.* the oviducts, *sp.* the spermathecæ. The nerve-cord (*n.*) and the septa (*s.*) are also shown. (Mainly after Vogt and Yung.)

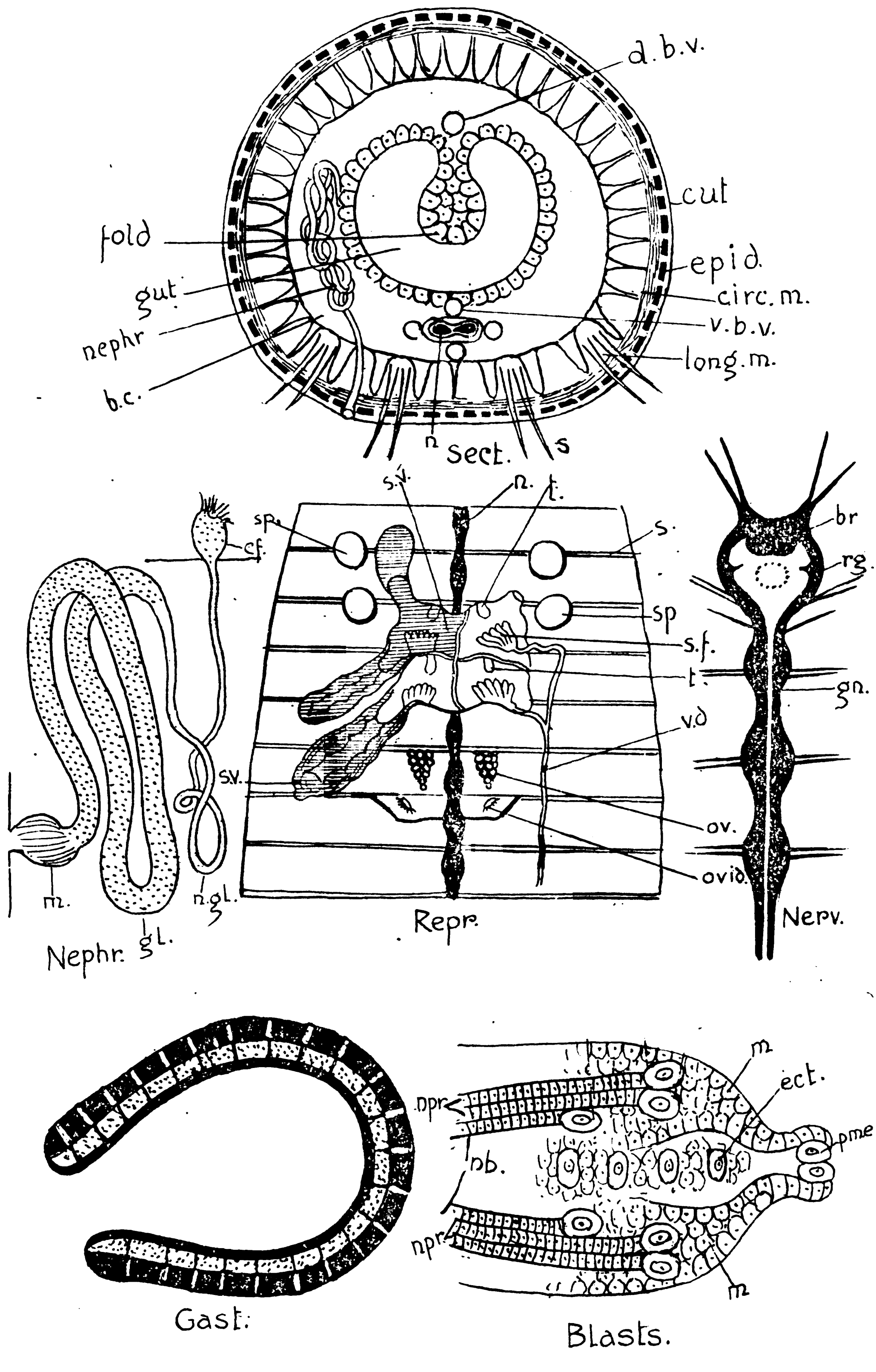
To the right (*Nerv.*) is the anterior part of the nervous system, showing the brain (*br.*), the œsophageal ring (*rg.*) surrounding the gut, *gn.* one of the paired ganglia.

To the left is a diagrammatic nephridium (*Nephr.*), showing the ciliated funnel (*f.*) and a septum on which it lies, the non-glandular (*n. gl.*) and the glandular (*gl.*) parts of the coiled tube, *m.* the terminal muscular region,

Below this is a diagrammatic section of the gastrula (*Gast.*), showing the internal hypoblast and the external epiblast cells.

To the right is a figure (*Blasts*) of the ventral surface of an embryo, showing some of the superficial ectoderm cells (*ect.*), the mesoblast (*m.*), the primary mesoblasts (*p. me.*), the neuroblasts (*nb.*), the nephridioblasts (*npr.*). The primary "blasts" in each case are the large terminal cells. (After Wilson.)

Earthworm.


d.b.v.
cut
fold
epid.
gut
circ.m.
v.b.v.
nephr
long.m.
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n
s
sect.
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ov.
ovid.
m.
n.gl.
gl.
Nephr.
Repr.
Nerv.
m
ect.
npr
pme
nb.
npr
m
Gast.
Blasts.

originate, according to Kleinenberg, independently of the ventral cord from a median unpaired apical plate of ectoderm, while according to Wilson they arise along with the ventral cord, and have their foundations in the thickened anterior end of each of the two neural rows.

The history of the *excretory system* is complex. (*a*) At the anterior end of young embryos, a group of ectoderm cells, dorsal in position, forms a larval excretory organ, which wholly disappears in later stages. (*b*) Next appear two ciliated canals in the anterior region, closed internally, opening on the head. These are known as "provisional nephridia" or "head-kidneys." They degenerate as the permanent excretory organs develop. (*c*) The numerous permanent nephridia are for the most part ectodermic, arising from the rows of nephridial cells already described. Two parts of each nephridium, however, have a mesoblastic origin, viz., the innermost part—the ciliated funnel, and the peritoneal investment which ensheathes the whole organ.

By the invagination of the blastosphere, a globular gastrula cavity is formed. This forms the archenteron,—the future *mid-gut*,—and elongates with the growth of the embryo. To the completion of the entire alimentary canal, however, two other processes are necessary, an in-tucking of ectoderm from in front—the *stomatodæum*—which pushes the archenteron backwards and forms the future pharynx, and a similar in-tucking of ectoderm from behind—the *proctodæum*—which meets and fuses with the archenteron, and forms the anus and a small portion of the posterior gut. As this compound formation of the gut is general among animals, we may restate it in a tabular form :—

Alimentary Canal or Gut.	Anterior ectodermic invagination—the stomatodæum or "fore-gut."
	Median gastrula cavity lined by endoderm—the archenteron, mesenteron, or "mid-gut."
	Posterior ectodermic invagination—the proctodæum or "hind-gut."

So far, then, the ectoderm primarily forms the epidermis,

and secondarily the nervous system, the greater part of the nephridia, and the setæ, while it is also tucked in to form the beginning and end of the gut. The endoderm forms the internal lining of œsophagus, crop, gizzard, and the intestine, except the last little bit which is due to the ectoderm. Everything else arises from the mesoderm. But this layer requires further analysis.

The mesoderm begins with the *two primary mesoblasts* already described. These multiply and form *mesoderm bands*, which, insinuating themselves between ectoderm and endoderm, proceed to surround the gut. At the same time, some of the mesoderm cells become migratory, wander on to the head, and also surround the gut, before the final trunk musculature is completed. The *migratory mesoblasts* of the trunk appear to form a special larval musculature precociously developed, in order to enable the embryo to manage the enormous mass of albumen (absorbed from the capsule) with which its body is distended. The mesoderm bands grow in strength, and form a complete ring encircling the archenteron.

Origin of the body-cavity. The mesoderm bands, growing in strength, become two-layered. These two layers separate, the inner (splanchnic) cleaving to the gut, the outer (somatic) clinging to the body-wall. The space between them is the *body-cavity* or *cœlome.* But as the separation of somatic and splanchnic layers takes place, partitions are also formed transversely, to become the septa which partition off the body-cavity into a series of segments. The cavity of the pre-oral segment or prostomium differs somewhat from that of the others, being from the first unpaired, instead of including two lateral cavities one on each side of the gut.

As to the *blood-vessels*, the ventral or sub-intestinal appears first, as a space between the wall of the archenteron and the underlying mesoderm ; the dorsal vessel has a double origin, arising from the fusion of two lateral vessels which develop like the ventral. The important point is, that the blood-vessels are at first long lacunar spaces, which gradually acquire definite walls. By and by the "hearts" and other complications in the vascular system appear.

The *reproductive organs*, though probably arising from

cells which have kept to some extent apart from the formation of the embryo, certainly appear in association with the mesoderm.

The Lob-Worm—*Arenicola piscatorum*:—a type of the marine Chætopods or Polychæta.

Habits.—On the flat sandy beach uncovered at low-tide, the "castings" of the lob-worm are very numerous. There the fishermen seek the worms for bait, and have to dig deep, for the burrowers rapidly retreat far into the sand. The burrows of the lob-worm are cylindrical tubes, lined by a yellowish-green secretion, and the surrounding sand is often discoloured by some change in which the organic juices convert the mineral particles of iron into oxides. The tubes are at first vertical, and afterwards oblique or horizontal.

The lob-worm burrows like the earthworm—eating the sand for the sake of the organic particles or small organisms which it contains. The sandy castings, which pass from the end of the food-canal, and are got rid of at the mouth of the tube, fall into spiral coils. When getting rid of the castings, the worm lies with its tail upwards and its head downwards, or with its body bent like a bow; when the tide comes in, the mouth may protrude. The animal is able to turn in its burrow.

External Appearance.—The lob-worm varies in length from eight inches to a foot, and at its thickest part is about half an inch in diameter. There are three regions in the body:—(*a*) the anterior seven segments, of which all but the first have bristles; (*b*) the gill-bearing region of thirteen segments; (*c*) the thinner posterior part of variable length, without either bristles or gills. The head-lobe is very small; there are no tentacles or eyes. Anteriorly a soft proboscis is protruded. The anterior region is greenish-brown, the middle region yellowish-red, the posterior region yellowish; but there is some variability.

Skin and Muscles.—Each segment is marked by several rings; there are numerous warts on the posterior region. Most externally lies the cuticle, then the pigmented epi-

dermis, then the circular and the longitudinal muscle-fibres.

Appendages.—Unlike many of the marine Annelids which have on each segment well-developed outgrowths or parapodia, divided into a dorsal notopodium and a ventral neuropodium, *Arenicola* has very rudimentary appendages. This reduction of appendages must be associated with the animal's mode of life; the same is true of many tube-inhabiting worms. The first segment has no trace of appendages, the next nineteen have rudiments. The dorsal part consists of a tuft of bristles, whose bases are enclosed in a sac;—the ventral part, separated by a short interval, bears several hooks.

The Nervous System is in its general features like that of the earthworm, but ganglia are not developed. In the ventral nerve-cord, the ring round the gullet, and the slight cerebral enlargement which represents a brain, nerve-cells occur diffusely scattered among the nerve-fibres. Along the dorsal surface of the nerve-cord run two "giant-fibres" like those in the earthworm. Sense-organs are represented only by a pair of otocysts, one on each side of the œsophageal nerve-ring. Each is a roundish sac containing fluid and calcareous particles.

Food-Canal.—The mouth is at the end of a protrusible cup-like proboscis; the gullet has smooth walls, and bears an anterior and a larger posterior pair of glands which secrete a yellowish fluid perhaps digestive; the succeeding part of the gut is covered with yellow cells and many blood-vessels, and is divided into rings; the terminal portion is full of sand from which the nutritive matter has been absorbed; the anus is at the very end.

The Body-Cavity is spacious, except in the tail region, and contains a fluid. Anteriorly there are three transverse, partly muscular, partitions or mesenteries which moor the gullet; in the tail region there are many such; the median part of the gut swings freely. Posteriorly there are also oblique partitions which divide the segments into a median and two lateral chambers.

The Vascular System.—The blood has a bright red colour. It flows forward in a dorsal vessel, running along the mid-dorsal line of the gut, backward in a ventral vessel below

the gut. Two sub-intestinal vessels lie between the ventral vessel and the gut, and receive tributaries from the anterior gills. On each side of the digestive part of the gut there is a lateral vessel.

Just behind the posterior pair of œsophageal glands lies a very contractile heart. It consists of two lateral chambers, or ventricles, each of which receives blood from the dorsal vessel, from a sub-intestinal vessel, and from a lateral vessel, and drives blood into the ventral vessel. Each of the lateral vessels before entering the heart expands into a kind of auricle.

The longitudinal vessels are all connected by transverse branches. From the ventral vessel arise afferent branchial vessels. From the seven posterior gills efferent branches enter the dorsal vessel; while those from the six anterior gills join the sub-intestinals. Each efferent vessel gives off a branch to the skin, while the dorsal and sub-intestinal vessels give off numerous branches to the walls of the gut. It seems that the flow of the blood is not always quite the same.

Respiratory System.—There are thirteen pairs of gills. Each is a tuft of thread-like branches, through the thin walls of which the red blood shines. As the papillæ on the proboscis are hollow and contain vessels, they are doubtless of respiratory significance. Indeed, the gills may be regarded as exaggerated papillæ.

Excretory System.—In the anterior region, from the fifth to the tenth segments, there are six pairs of nephridia. Each consists of three parts—a funnel opening into the body-cavity, a glandular portion, and a bladder communicating with the exterior.

Reproductive System.—The sexes are separate and similar. The reproductive organs are very simple modifications of the peritoneal membrane of the body-cavity. They are developed in close association with the nephridia. The reproductive cells are liberated into the body-cavity, and there matured. In August and September they pass out by the nephridia. Nothing certain is known in regard to the development.

A general contrast of the modes of Development in different Annelids.

A. "Larval" Types as in marine Chætopods, *Polygordius*, etc.	B. "Fœtal" Types as in Earthworm, Leech, etc.	
Development indirect. A free-swimming Trochosphere stage, with trunk almost or wholly suppressed, with head-region greatly developed, with adaptations to free marine life.	Development direct, within egg-capsule; Trochosphere stage almost or wholly suppressed.	
	Lumbricus type with little nutritive material in ovum, with gastrula formed by invagination (embolic).	*Clepsine* type with much nutritive material in ovum, with gastrula therefore formed by overgrowth (epibolic).

By far the most important larval form among Annelids is that known as the Trochosphere or Trochophore. It occurs as such in the great majority of marine Chætopods, and in more or less modified guise in many other worm-types, and also in Molluscs. Moreover, there are many reasons for regarding the Trochosphere as to some extent like the ancestor of Annelids, especially as there are a few forms like *Dinophilus*, which do not advance far beyond the structure of a Trochosphere.

Picture a normal gastrula such as occurs in the development of many marine Chætopods. It is a two-layered sac of cells with a cavity between the external ectoderm and the invaginated endoderm. The blastopore or mouth of the gastrula lies at the ventral pole. A ring of cilia frequently forms an equatorial girdle. Now, suppose that the apical (aboral) region of this symmetrical gastrula be tilted forward. The ring of cilia becomes distinctly pre-oral, and internal to it there may be a nervous ring. In the apex there is a ganglion with a nerve running backwards. Picture a backward growth of the posterior region which lies opposite to

the apex, and furthermore, the formation of fore-gut and hind-gut by anterior and posterior invaginations of ectoderm, which communicate with the original gastrula cavity or archenteron. The larval food-canal has thus a curve concave ventrally. In the primitive body-cavity (really the segmentation cavity) there lie posteriorly a few mesoblast cells which have a very varied future before them.

Such a larva is called a trochosphere or trochophore. Its chief characteristics are, (1) the prominent pre-oral region with its apical ganglion and ring of cilia, (2) the three-fold origin and concave curve of the gut, (3) the nature of the larval body-cavity and the posterior primitive mesoblast cells which lie in it, and (4) the fact that the future formation of segments and growth into worm-like form takes place in a posterior area in front of the anus.

But we must notice a few complications of less constant occurrence. The pre-oral ring of cilia is often accompanied by a post-oral, and there may also be an ad-oral ring between the other two, and also an apical tuft. The larva is thus very efficiently adapted for free swimming. The apical ganglion may be accompanied by a pigment (optic ?) spot and other sensory structures. In the head there is often a pair of larval excretory tubes which afterwards disappear.

It is important to understand that this Trochosphere arises by a gradual modification of the gastrula, that most of it corresponds to the future head, and the apical ganglion to the brain, that the formation of segments takes place in a posterior area of growth, between the post-oral ring of cilia and the anus. This form of larva is very common, either as such, or in some modified guise.

Pedigree of Annelids.—According to Lang, the Chætopods are derived from a leech-like type, this from a Polyclade Turbellarian, and this from a Ctenophore. According to Sedgwick, the Annelids are derived from an Actinozoon-like ancestor. But we cannot here discuss these possibilities, nor the difficult questions concerned with the meaning of segmentation or metamerism.

DIAGRAM IX.

ARENICOLA.

Aren. 1 shows the external form, the tufts of setæ, the thirteen gills. The tail region is cut short. (After Cunningham and Ramage.)

Aren. 2 shows a dissection of the anterior region; *pap.* the papillæ on the proboscis, *sept.* three anterior mesenteries or septa, gl^1. and gl^2. the glands of the gullet (*g*), *neph.* the nephridia, *b. s.* the sacs for the bristles, *n.* the ventral nerve-cord, *int.* the beginning of the intestine, *ht.* the heart. (After Vogt and Yung.)

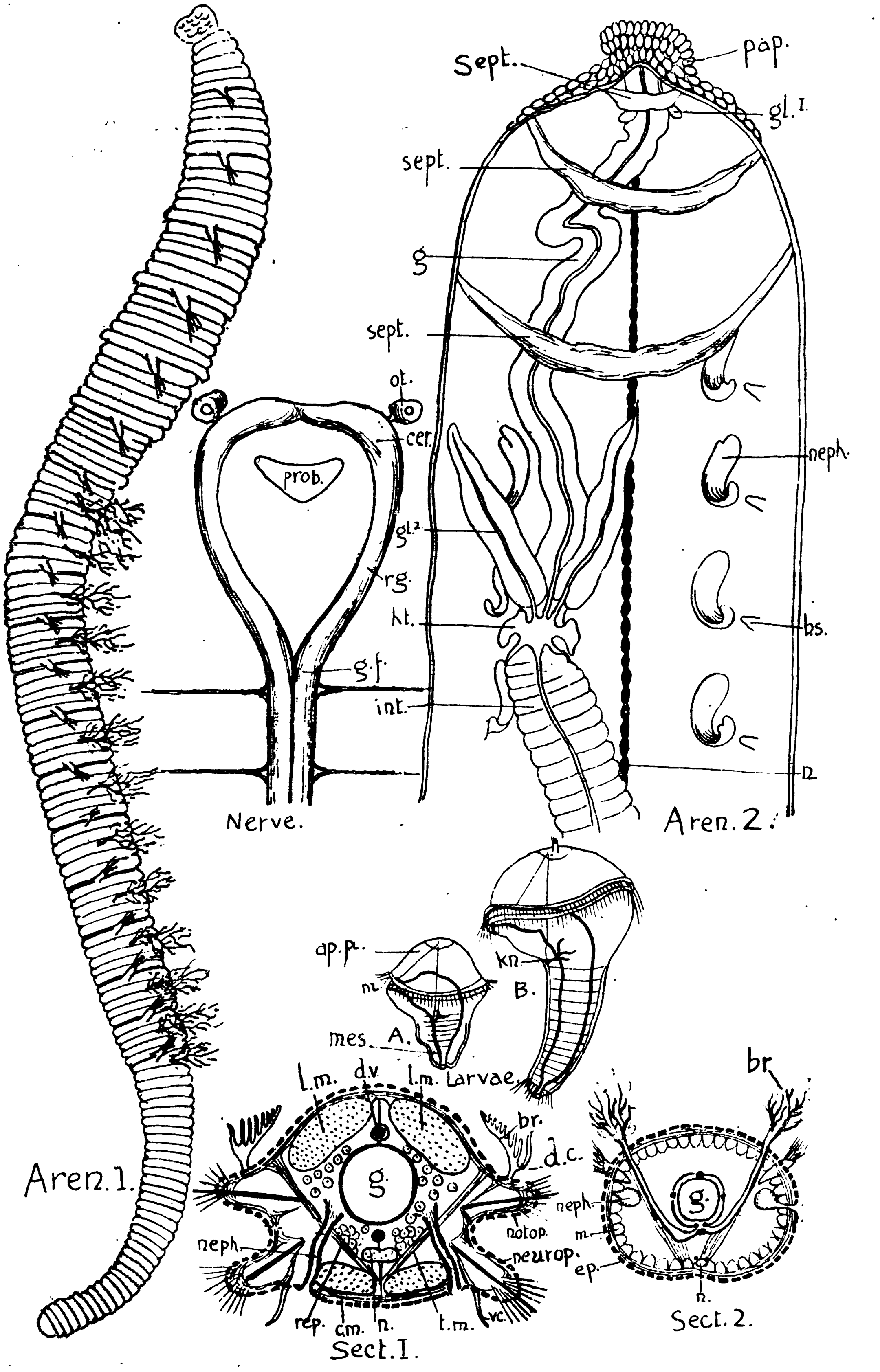
Nerve shows the anterior part of the nervous system; *cer.* the cerebral region, *ot.* the associated otocysts, *prob.* the relative position of the proboscis, *rg.* the œsophageal ring, *g. f.* the position of the giant-fibres. (After Vogt and Yung.)

Sect. 1 shows a transverse section of a typical Polychæte; the dotted external line represents the epidermis, *c. m.* the circular muscles, *l. m.* the longitudinal muscles, *n.* the ventral nerve-cord, *t. m.* transverse muscles, *rep.* the position of the reproductive organs, *neph.* part of a nephridium, *g.* the gut, *d. v.* the dorsal blood-vessel, *neurop.* the neuropodium, with ventral cirrus (*v. c.*), *notop.* the notopodium with dorsal cirrus (*d. c.*), *br.* the branchiæ or gills. (After Lang.)

Sect. 2 shows a transverse section of *Arenicola*, showing the epidermis (*ep.*), the muscles (*m.*), a nephridium (*neph.*), the gut (*g.*), a tuft of bristles above the opening of the nephridium, *n.* the ventral nerve-cord, and indications of the blood-vessels associated with gills and gut. (After Cosmovici.)

Larvæ A and B are developing trochospheres, *m.* is the mouth, *ap. p.* the apical plate, *mes.* the beginning of mesoblastic segments, *kn.* an anterior kidney-tube. The anterior ring of cilia, the curve of the food-canal, and the growth and segmentation of the posterior region are evident. (After Hatschek.)

Arenicola.



pap.
Sept.
gl. I.
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sept.
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Larvae.
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Sect. I.
Sect. 2.

General Survey of Chætopoda.

I. *Oligochæta.*

Of *Lumbricus* there are many species, *e.g.*, the common earthworm *L. terrestris*, the dunghill worm *L. fœtidus*, and *L. communis* or *trapezoides*, whose ova usually form twins. We may conveniently include under the title "earthworms" a great array of animals more or less like *Lumbricus*, and usually described as terricolous Oligochæta. The senior student should make himself acquainted with the four groups—LUMBRICINI, GEOSCOLECINI, ACANTHODRILINI, and EUDRILINI, and with the divergent branch MONILIGASTRES, but it is enough for us to notice here that the modern classification is mainly based on the modifications of the excretory system. The largest " earthworm " is a Tasmanian species—*Megascolides gippslandicus*—measuring about six feet in length, said to make a gurgling noise as it retreats underground.

To these must then be added a number of families, *Tubificidæ*, *Enchytræidæ*, etc., which live in mud and water, and are often called limicolous Oligochæta. Of these a very common representative is the little river worm *Tubifex rivulorum*, often found in the mud of brooks, and well suited in its transparency and small size for microscopic examination. Also notable is the fresh-water *Nais*, with remarkable powers of asexual budding.

The advanced student should take note of the leech-like *Branchiobdella*, which is parasitic on the crayfish, and apparently an abnormal Oligochæte.

The two sets of which *Lumbricus* and *Tubifex* are types, are united as Oligochæta, *i.e.*, with few setæ, in contrast to the marine Chætopods where the bristles are numerous, the Polychæta.

II. *Polychæta.*

Living in surroundings usually very different from those of the more or less subterranean earth- and mud-worms, the marine Polychæta have a richer development of external structures, and a more complex life-history. From the sides of the body-rings distinct outgrowths form the first genuine legs. These, known as parapodia, bear bundles of bristles, and are typically divisible into a firmer ventral neuropodium, often used for creeping, and a more leaf-like dorsal notopodium often respiratory. Special outgrowths of skin, on which blood vessels are spread out, form the first genuine gills, and soft processes or cirri are present on some or all of the rings. The head is equipped with antennæ and other tactile organs, and not unfrequently with eyes, ear-sacs, and other sensitive structures. The sexes are usually separate, and the development includes a metamorphosis, the larval trochosphere being quite different from the adult worm.

(*a*) Some of these marine Polychætes lead a free and more or less active life, crawling between tidemarks or on the sea-bottom, burrowing in the sand, or swimming in the open water. These Errantia have well-developed appendages, and a large pre-oral segment, and are generally furnished with eyes and well-developed antennæ. Gills are usually associated with the dorsal parts of the parapodia. Most of them feed on

other animals, and have sharp "horny jaws," while the anterior part of the gut is protrusible as a proboscis.

Nereis and *Nephthys* are two common genera, species of which may be unearthed by digging in the sand close to rocks, though at times these or other species are seen swimming freely. The sea-mouse, *Aphrodite*, has iridescent bristles, a feltwork of matted hair covering large gill-plates which lie along its back, a very large muscular pharynx, and a gut with numerous irregular branches extending throughout the body. A very common shore form a little like a small *Aphrodite* is *Polynoe*. As an actively errant worm, with well-developed eyes, *Alciope* may be noted, and the family of Syllids is remarkable for the unusually prolific asexual budding, which sometimes results in a chain or even an irregular branched aggregate of individuals. As the cuticle is often iridescent, and as the red blood may shine through the skin, these marine worms are frequently beautiful. The list of nymphs and goddesses has been the source of such titles as *Nereis*, *Aphrodite*, *Eunice*, and *Hermione*, and one can almost believe the legend, according to which a specialist on Errantia christened his daughters after his seven favourites.

(*b*) Other marine Polychæta, however, lead a more sluggish life within various kinds of tubes, limy, sandy, papery, or gelatinous. As one would expect, their parapodia are minute, apt to degenerate, and often used solely for clambering within the tube. The pre-oral region is small, but the anterior rings usually bear gills, cirri, and tentacles, often in rich profusion. These Sedentaria rarely have a protrusible pharynx, and never "jaws." Most of them feed on minute Algæ swept in by the cilia on the tentacles and other structures about the mouth.

The fisherman's lob-worm (*Arenicola piscatorum*) burrows in the sand like *Lumbricus* on shore, and forms the familiar castings on flat beaches. Its parapodia are much reduced, and the body is markedly divisible into a swollen anterior, a gill-bearing median, and a narrower posterior region. Common also on the shore within a tube of glued sand particles is *Terebella* or *Lanice conchilega*, where the excretory tubes are partly united by a longitudinal tube in a manner suggestive of the segmental duct which connects the nephridia of a young Vertebrate. The twisted limy tubes of *Serpula* are common outside shells and all sorts of marine objects, and the animal bears a stopper or operculum, with which it closes the mouth of its tube, but through which it probably at the same time breathes. In deep water, within a yellow parchment-like tube, *Chætopterus* may be dredged, perhaps the strangest form of all.

III. *Echiuridæ.*

In holes in the rocks on some of the warmer European coasts lives a curious "worm"—*Bonellia viridis*, of a beautiful green colour, with a globular body and a long, grooved, anteriorly forked, pre-oral protrusion. Such at least is the female, but the male is microsopic in size, hopelessly degenerate, and lives parasitically in or on its mate. The male resembles in some ways a Turbellarian, is mouthless and gutless, and little else than a migratory spermatophore. By means of cilia, it moves from one part of the female to another, and fertilises the eggs in

a modified excretory tube, which serves the female *Bonellia* as a uterus. Here illustrated in extreme, we see the usual inequality (in size) between the sexes.

Less abnormal than *Bonellia*, are the genera *Echiurus* and *Thalassema*.

In this small sub-order, the adults have at most indistinct traces of the segments which the young forms exhibit. Nor are there parapodia, cirri, or gills, but setæ are always represented (except in the male *Bonellia*) by two anterior bristles, and in *Echiurus* by posterior spines as well. The nerve-cord is unsegmented, and there is but a slight anterior ring without a brain. The anterior part of the body forms a muscular, well-innervated, ciliated proboscis, with the mouth deeply situated at its base; the gut is much coiled, bears a curious adjacent tube known as the "collateral intestine," and a pair of excretory "anal glands" opening into the body-cavity by ciliated funnels. There is a terminal anus. There are dorsal and ventral blood-vessels, and two or three pairs of nephridia, one or more of which function as reproductive ducts. The sexes are separate, and the reproductive elements are formed on the walls of the body cavity, into which they are liberated. There is a metamorphosis in development, the larvæ differing from the adults in many ways, *e.g.*, in being segmented.

Appendix (1) *to Chætopoda.*

PRIMITIVE CHÆTOPODS AND ANNELIDS (Archi-Chætopoda and Archi-Annelida).

An aberrant Chætopod type is represented by *Saccocirrus*, a small marine "worm" with many primitive characteristics. The body is segmented, and very uniform throughout; the pre-oral region is small, but the mouth-segment is large; there are bundles of setæ on the rings; the nervous system remains embedded in the epidermis.

More primitive, however, are the Archi-Annelida represented by *Polygordius*, *Protodrilus*, and *Histriodrilus*—all marine. The small body is segmented and uniform; there are no setæ, parapodia, cirri, or gills, but the head bears a few tentacles; as in *Saccocirrus* the pre-oral region is small, and the segment around the mouth is large; the very simple nervous system is retained in the epidermis.

Polygordius is a thin worm, an inch or more in length, living at slight depths in sand or fine gravel, often along with the lancelet. It has a few external cilia about the mouth in a pair of head-pits, and sometimes on the body; it moves like a worm, but has no bristles. It feeds like an earthworm, or sometimes more discriminatingly on unicellular organisms. The females are usually larger than the males, and in some species break up at sexual maturity. The development includes a metamorphosis, and the larvæ seem to throw some light on the nature of the ancestral Annelids. They are ciliated, free-swimming, light-loving, surface animals, feeding on minute pelagic animals, seeking the depths as age advances. According to some, the larva represents a primitive unsegmented ancestral Annelid with medusoid affinities;

according to others, the larval characteristics are adaptive to the mode of life, and without historic importance.

Protodrilus is even smaller than *Polygordius*, with more cilia, mobile tentacles, and two fixing lobes on the posterior extremity; the movements are Turbellarian-like, the reproductive organs hermaphrodite, the development direct. *Histriodrilus* is parasitic on the eggs of the lobster.

Appendix (2) *to Chætopoda.*

PARASITIC AND DEGENERATE CHÆTOPODS. MYZOSTOMATA.

The remarkable forms (*Myzostoma*) included in this small class, live parasitically on feather-stars, on which they form galls. They are regarded as divergent offshoots from primitive Annelids, the larval form showing some distinctly Chætopod characters. The minute disc-like body is unsegmented, and bears five pairs of parapodia, each with a grappling hook, with which five pairs of suckers usually alternate. There are also abundant cirri. The skin is thick, the body muscular, the nervous system is concentrated in a ganglionic mass, which encircles the gullet and gives off abundant branches. There is a protrusible proboscis and a branched gut; the mouth and anus are ventral. The ova arise in the reduced body-cavity, and pass out by the anal aperture, *via* three meandering oviducts. The testes are paired, branched, and ventral, with associated ducts, which open anteriorly on the side of the body. The sexual relations are interesting, for one species is hermaphrodite and another unisexual, between which there is an intermediate species with ovaries and rudimentary testes. The hermaphrodite form may bear on its body dwarfish males, analogous to the complemental pigmies on some hermaphrodite barnacles.

Class DISCOPHORA OR HIRUDINEA. Leeches.

Most leeches are worm-like aquatic animals, with blood-sucking propensities, but some live in moist soil, and others keep to the open surface, while the parasitic "vampire" habit, familiarly illustrated by the apothecary's ancient panacea, is in many cases replaced by carnivorous habits and predacious life. The medicinal leech (*Hirudo*) is typical of the majority, for it lives in ponds and marshes, and sucks the blood of snails, fishes, frogs, or of larger available victims. The giant leech (*Macrobdella valdiviana*), said to measure $2\frac{1}{2}$ feet in length, is subterranean and carnivorous, while the wiry land-leeches (*Hæmadipsa*, etc.), of Ceylon and other parts of the East move in rapid somersaults along

the ground, fasten on to the legs of man or beast, and gorge themselves with blood. In every leech there is a posterior attaching sucker, while the mouth in the ecto-parasitic types is more literally suctorial. By attaching the head-end and loosening the tail, then fixing the tail and extending the anterior region, many leeches move very quickly and deftly, while at other times, or in other forms, the mode of locomotion is by graceful serpent-like swimming, or by gentle gliding after the manner of snails. The hungry horse-leeches, "whose daughters cry Give, Give," are species of *Hæmopis*, greedily suctorial though their teeth are too small to be useful in blood-letting; but the popular name is also applied to species of the common genus *Aulastoma*, whose members are carnivorous. Other common leeches are species of *Nephelis*, predacious forms with indiscriminating appetites, and the little *Clepsine*, also common in our ponds, notable for its habit of carrying its young about on its belly. Numerous marine forms prey upon fishes and other animals, *e.g.*, the "skate-sucker" *Pontobdella*, with leathery skin rough with knobs, and *Branchellion* on the Torpedo, remarkable for numerous leaf-like respiratory plates on the sides of its body. Perhaps the strangest habitat is that of *Lophobdella*, which lives on the lips and jaws of the crocodile.

Type. The Medicinal Leech (*Hirudo medicinalis*).

This is the commonest and most familiar of leeches, once so constantly used in the practice of medicine that leech became synonymous with medical practitioner. It lives in ponds and sluggish streams, and though not common in Britain, is very abundant in many regions of the Continent, where leech farms, formerly of great importance, are still to be seen. Leeches feed on the blood of fishes, frogs, and the like, and are still caught in the old fashion on the bare legs of the callous collector. As animals are naturally averse to blood-letting and hard to catch, leeches take as much as they can hold when they are at it, and once gorged with blood will keep on slowly digesting for many months, it may be indeed for a year. Watched in a glass jar, the leech

will be seen to move by alternately fixing and loosening its oral and posterior suckers, while some slight provocation, such as some drops of chloroform or alcohol, will induce the animal to swim about both actively and gracefully. The animal will also be seen to cast off from its skin thin transparent shreds of cuticle,—a process which, in natural conditions, usually occurs after a heavy meal, when the animal as if in indigestion spasmodically contracts its body, or rubs itself on the stems of water-plants. As we shall afterwards see, numerous eggs are laid together in cocoons deposited in damp earth near the edge of the pool. Thence after a direct development, young leeches emerge and make for the water.

External Features.—The leech usually measures from two to six inches in length, and appears cylindrical or strap-like according to its state of contraction. The slimy body shows over a hundred skin-rings; the dorsal surface is beautifully coloured with distinct rows of spots in contrast to the irregularly mottled under-side; the suctorial mouth is readily distinguished from the unperforated hind sucker, above which on the dorsal surface the alimentary canal may be seen to end. More careful examination shows five pairs of little black "eyes" distributed on the first eight rings of the head, the swollen protrusion of the male organs which open on the middle ventral line between rings 30 and 31, a similar aperture of the female organs five rings further back, seventeen small openings down each side of the ventral surface through which a whitish fluid may be squeezed—the apertures of the excreting organs. The skin-rings, of which there are 102 in all, are superficial wrinkles, disguising the true body-segments, which are determined by the internal arrangements of nerve-centres and excretory tubes. The true segments are 26 in number, and this fact may be recognised even externally, since 26 of the 102 skin-rings are distinguished from their neighbours by the possession of numerous "sensory spots." The number of sensory rings is thus equal to the number of true segments. There are usually five skin-rings to each segment, but fewer at each end. In illustration, we may note that the male aperture between rings 30 and 31 is on the tenth segment, and the female aperture between 35 and

36 on the eleventh. It is also worth noticing that the skin of segments 9–11 is especially slimy, forming the so-called clitellum or saddle, the secretion of which makes the cocoon for the eggs.

The *skin* is so closely connected with the connective and muscular tissue lying beneath that little will be made of its structure except by the microscopic examination of sections. Most externally lies the cuticle—a product of the epidermis—periodically shed as we have already noticed. In this shedding some of the genuine epidermal cells are also thrown off. These are somewhat hammer-like units with the heads turned outwards, while the spaces between the thick handles contain the pigment and the fine branches of blood-vessels. As the latter come very near the surface a respiratory absorption of oxygen and outward passage of carbonic acid is readily effected. Opening between the epidermal elements, but really situated much deeper, are numerous long-necked, bottle-shaped glandular cells, the contents of which form the slimy stuff so abundant on the skin. Underneath the epidermis there is much connective-tissue, and not a little pigment, yellow and green, brown and black in colour.

The *muscular system*, by means of which the animal moves so deftly, consists of long spindle-shaped cells arranged externally in circular bands like the hoops of a barrel, internally in longitudinal strands like staves. Besides these there are numerous muscle-bundles running diagonally through the body, or from dorsal to ventral surface, and there are other muscles associated with the lips, tooth-plates, and pharynx.

The *body-cavity* is almost quite obliterated in the adult leech, where the predominant connective tissue has filled up nearly every chink and crevice. It is to be seen in the embryo, and its remnants may be detected here and there in the adult. The virtual absence of the body-cavity, and the spongy compactness of the whole animal, make the leech a tedious subject to dissect.

The *nervous system* mainly consists of a pair of dorsal ganglia lying above the pharynx, and of a double nerve-cord with twenty-three ganglia lying along the middle ventral line. The dorsal (or supra-œsophageal) ganglia are connected with the most anterior (or sub-œsophageal) pair on the ventral

DIAGRAM X.

The Leech.

To the right is shown (after Whitman) the external morphology of the leech, the 26 segments, the 102 rings, the openings of the 17 pairs of nephridia, the position of the 10 "eyes," of the sensory spots on every fifth ring, the openings of the male and female ducts.

Sect. is a diagrammatic representation of a cross section; *cut.* the cuticle, *epid.* the epidermis, *c. m.* the circular muscles, *l. m.* the longitudinal muscles, *g.* the gut with two side pockets, *d. b. v.* the dorsal blood-vessel, *v. b. v.* the ventral blood-vessel enclosing the nerve-cord (*n.*), *l. b. v.* the lateral blood-vessels, *neph.* a nephridium and its bladder, *t.* a testis and part of the associated duct.

Gut shows the food-canal with pharynx (*ph.*), pouched crop (*cr.*), stomach (*st.*), and rectum (*r.*).

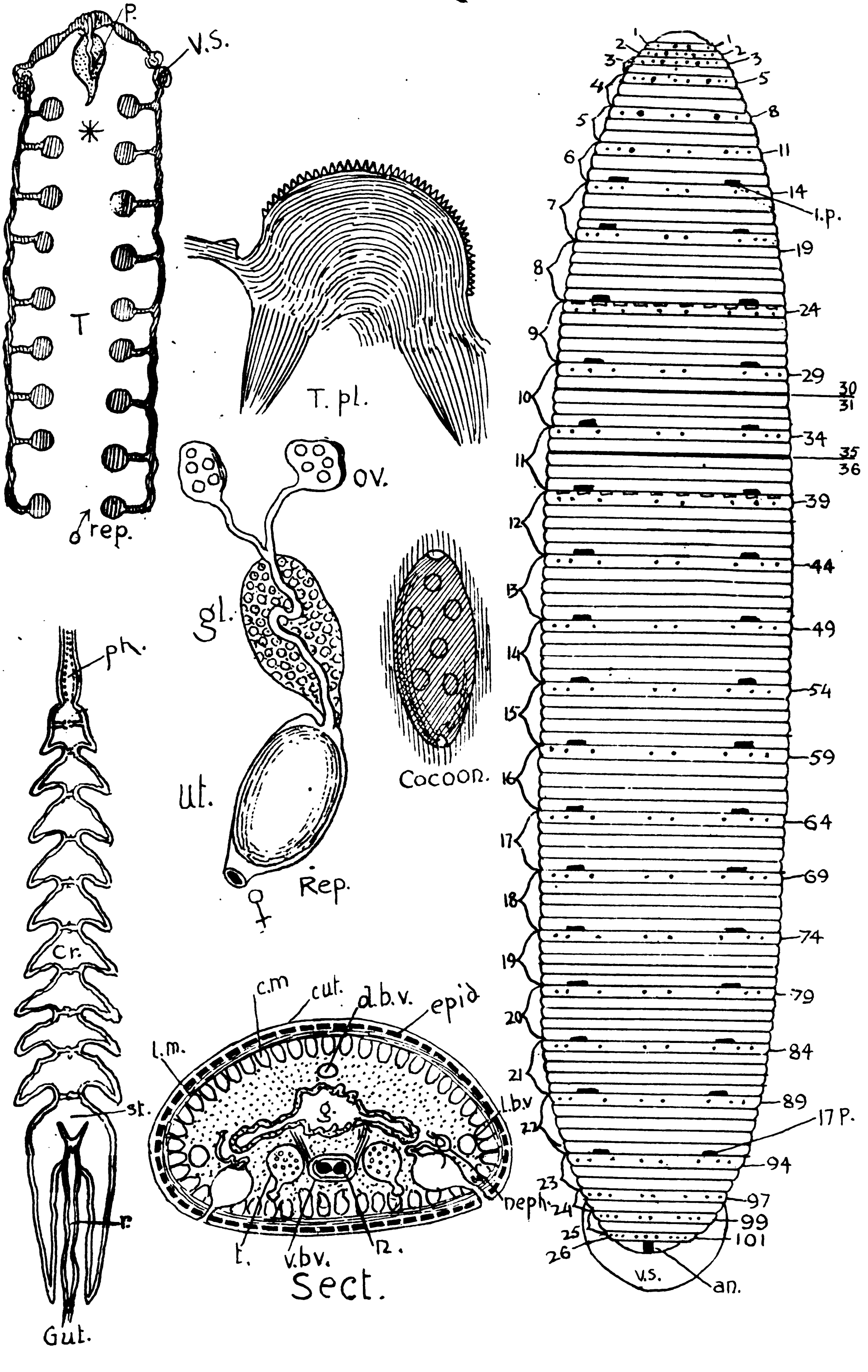
Above this is the male reproductive system, with nine pairs of testes (*T.*) connected by a vas deferens, with anterior seminal vesicles (*v. s.*) and penis (*p.*). The asterisk indicates the position of the female reproductive system.

The latter is shown on a large scale, *ov.* the ovaries, *gl.* the gland around the united oviducts, *ut.* the uterus. To the side is a cocoon containing eggs. (After Vogt and Yung.)

The figure marked *T. pl.* shows a tooth-plate with marginal teeth. At its inferior corners the associated muscles are shown. (After Vogt and Yung.)

Diagram X.

Leech.



chain, by a narrow nerve-ring surrounding the beginning of the gut. From the dorsal centres nerves proceed to the "eyes" and anterior sense-spots, from the ventral centres the general body is innervated, and from the beginning of the ventral chain special nerves supply the alimentary canal, forming what is called a visceral system.

The *sense-organs* of the leech are ten so-called "eyes," besides numerous sense-spots usually occurring on every fifth skin-ring. The eyes are distributed on the first eight rings, five on each side, and look like little black spots. Microscopic examination of sections shows them to be definite cups, surrounded by connective tissue with black pigment. At the base of each cup a nerve enters, and breaks up into fibrils, which are continued into long sensory cells in the centre of the cylinder. These are surrounded by large clear cells, which may act like small lenses, and the mouth of the cup is covered with skin. Following the structure of a vertebrate eye, we may call the protective outside wall a sclerotic, the pigment layer a choroid, the sensitive cells in the centre a retina, and the surrounding clear cells lenses. But it would be bold to say that the leech really sees with its ten "eyes;" sensory organs they certainly are, but very blind eyes. The sense-spots which are distributed over the body in regular segmental order, look like simple homologues of the "eyes," differing, however, in having fewer clear cells and no pigment layer, while the sensitive cells in the centre are more obviously derived from the epidermis. We can only guess as to their function, whether it be tactile, olfactory, or otherwise.

The Alimentary System.—When the leech has firmly fastened itself to its prey by the hind sucker, it brings its muscular mouth into action, pressing the lips tightly on the skin, and protruding three chitinous tooth-plates which lie within. Each of these tooth-plates is worked by muscles, and is like a semicircular saw, for the edge bears from 60 to 100 small teeth. Rapidly these saws cut a triangular wound, whence the flowing blood is sucked into the mouth by the muscular pharynx. The process may be observed and felt by allowing a hungry leech to fasten on your arm. As the blood passes down the pharynx, it is influenced by the secretion of salivary cells which lie among the muscles, and exude

a ferment which prevents the usual clotting. The blood greedily sucked in gradually fills the next region of the gut, which bears on each side eleven storing pockets. These become wider and more capacious towards the hind end, the largest terminal pair forming two great sacs on each side of the comparatively narrow posterior part of the gut. As all the pockets point more or less backwards, it is evident why a leech to be emptied of the blood which it has sucked must be pressed from behind forwards. The pockets filled, the leech drops off its victim, seems to retire into more private life, and digests at leisure. The digestion does not take place in the pockets, but in a small area just above the beginning of the terminal part or rectum. This rectum, lying between the two last pockets, is separable from the true stomach just mentioned by a closing or sphincter muscle. It ends in a dorsal anus above the hind sucker.

The *vascular system* consists of four main vessels running longitudinally, one above the gut, one round about and obscuring the nerve-cord, and one on each side of the body. These are all connected with one another by looping vessels, and all give off numerous branches which riddle the spongy body. The main side vessels are most distinct, are contractile throughout, and give off to the skin, gut, and excretory organs, a rich supply of branches. The dorsal and ventral vessels, though quite distinct, are less definite, being rather regular blood-spaces than well-formed vessels. That the lateral vessels do most of the work of circulation is certain, but the precise course of the blood is not satisfactorily known. The blood itself is a red fluid with floating colourless cells diverse in form.

The *excretory system* includes seventeen pairs of excreting tubules or nephridia, opening laterally on the ventral surface, ending blindly within the body, but extracting waste-products from the blood-vessels which cover their walls. Each consists of two parts, a twisted horse-shoe-shaped glandular region where the actual excretory function is discharged, and a spherical, internally ciliated bladder opening to the exterior. Within the latter there is a whitish fluid in which microscopic examination shows numerous waste crystals.

The Reproductive System.—The leech, like many other Invertebrates, is hermaphrodite, containing both male and

female reproductive organs. The essential male organs or testes are diffuse, being represented by nine pairs, lying on each side of the nerve-cord in the middle region of the body. Each is a firm globular body, within which mother-sperm-cells divide into balls of sperms. The sperms pass outwards from each testis by a short canal leading into a wavy longitudinal male duct or vas deferens which gathers male elements from each side. This duct followed towards the head forms a coil (so-called seminal vesicle) as it approaches the ejaculatory organ or penis. From the coil on each side the sperms pass into a swollen sac at the base of the penis, where by the viscid secretion of special ("prostate") glands, they are glued together into packets or spermatophores. These pass up the narrow canal of the muscular penis, pass out on the middle ventral line between rings thirty and thirty-one, and are transferred in copulation to the female duct of another leech.

The female organs are more compact. The two small tubular and coiled ovaries are enclosed in a spherical bladder, the walls of which are continued as two oviducts which unite together in a convoluted common duct. This is surrounded by a mass of glandular cells, which exude a glairy fluid into the duct. Finally, the duct opens into a relatively large muscular sac—the "uterus," which opens through a sphincter muscle on the middle ventral line between rings thirty-five and thirty-six.

The favourite breeding time is in spring. Two leeches fertilise one another, uniting in reverse positions so that the penis of each enters the uterus of the other. Spermatophores are passed from one to the other, and the contained sperms may remain for a long time within the uterus, or, liberated from their packets, may work their way up the female duct, meeting the eggs at some point, or reaching them even in the ovaries. As considerable space has been given to a description of the earthworm's development, I shall only say that leeches present many similar embryonic features, confirming on embryological grounds what is otherwise probable, that the Hirudinea are true Annelids.

Classification—The Hirudinea include :—

1. Rhychobdellidæ, in which the fore-part of the pharynx can be protruded as a proboscis. There are anterior as well as posterior

suckers. The blood-plasma is colourless. The ova are large and rich in yolk; the embryos are hatched at an advanced stage, and soon leave the cocoon, which contains no albuminous fluid.

e.g., *Clepsine*, *Pontobdella*, *Branchellion*.

2. Gnathobdellidæ, in which there is no proboscis, but the pharynx usually bears three tooth-plates. The mouth is suctorial. The blood-plasma is red. The ova are small and without much yolk; the embryos are hatched at an early stage, and swim about in the nutritive albuminous fluid of the cocoon.

e.g., *Hirudo*, *Hæmopis*, *Hæmadipsa*, *Aulastoma*, *Nephelis*.

Appendix (1) *to Annelid Series.*

Class CHÆTOGNATHA—Arrow-Worms.

There are two little marine "worms," *Sagitta* and *Spadella*, which are so different from all others, that they have been placed in a class by themselves. It is possible to regard them as Annelids with three segments.

The translucent body, which is about an inch long, has three distinct regions,—a head bearing a ventral mouth with spines and bristles (whence the name Chætognatha), a median region with lateral fins, and a trowel-like tail.

The nervous system consists of a supra-œsophageal ganglion in the head, a sub-œsophageal about the middle of the body, long commissures between them, and numerous nerves from both. There are two eyes and various patches of sensitive cells.

The food-canal is complete and simple, it lies in a spacious ciliated body-cavity, which arises in the embryo as two pockets (cœlome-pouches) from the primitive gut-cavity or archenteron. Corresponding to the external divisions, the cavities of head, body, and tail are distinct.

There is no vascular system, nor are there any certain nephridia. It is possible that the latter may be represented by the genital ducts.

The animals are hermaphrodite, and the simple reproductive organs lie near one another posteriorly. The two ovaries project into the body-cavity, and their ducts open laterally where body and tail meet. The two testes project into the cavity of the tail, and their ducts have

internal ciliated funnels, and open on the tail. It is interesting to know that two reproductive cells are set apart at a very early stage, and that each divides into the rudiment of an ovary and of a testis.

The development is very regular. The eggs undergo complete segmentation; a gastrula is formed by the invagination of a hollow ball of cells; the body-cavity arises in the form of two pockets from the gastrula cavity or archenteron.

Appendix (2) *to Annelid Series.*

Class Rotatoria—Rotifers.

Rotifers are beautiful minute animals, abundant in fresh water, also found in damp moss, and in the sea. They owe their name and the old-fashioned title of wheel-animalcules, to the fact that the rapid movements of cilia on their anterior end produce the appearance of a rotating wheel. The food seems to consist of small organisms and particles caught in the whirlpool made by the lashing cilia. The little animals are tenacious of life, and can survive desiccation, though some instances of this are to be explained by the survival of the eggs, not of the individuals.

The body is usually microscopic, and is sometimes (*e.g.*, in *Melicerta* and *Floscularia*) sheltered within an external tube. There is no internal segmentation, but there are sometimes external rings, and a ventral outgrowth or "foot" is sometimes segmented. The anterior end bears, on a retractile ridge, the ciliated rings or "trochal apparatus."

The nervous system is a single dorsal ganglion with a few nerves. An unpaired eye and some tufts of sensory hairs are usually present.

The food-canal extends along the body in a well-developed cœlome, and the fore-gut contains a mill in which two complex hammers beat upon an anvil. The canal ends posteriorly on the dorsal surface between the body and the foot, and as the terminal portion also receives the excretory canals and the oviduct, it is called a cloaca.

There is no vascular system, but a nephridial tube of a primitive type lies on each side of the body, and opens posteriorly into the cloaca.

The sexes are separate, the reproductive organs are simple. Except in the marine parasite *Seison* and two other forms, the males are dwarfed and degenerate, destitute even of a true food-canal. In many cases at least, sexual union (effected by a penis) seems to be ineffective, and there is no doubt that many if not most Rotifers are parthenogenetic. The females lay three different kinds of eggs according to their conditions and cónstitution—either small ova which become males, or thin-shelled "summer ova," or thick-shelled "resting or winter ova," the two last developing into females. Many species, however, are viviparous. We include the Rotifers beside the Annelids proper, because it seems possible to regard them as derived from ancestors somewhat like Annelid larvæ.

Rotifers living in fixed tubes or envelopes,—*Melicerta*, *Floscularia*, *Stephanoceros*.

Free Rotifers,—*Notommata*, *Hydatina*, *Brachionus*.

Parasitic on the marine Crustacean *Nebalia*,—*Seison*.

Pedalion occupies a unique position; it has hints of appendages and a peculiar jumping motion.

Equally *incertæ sedis*, but plausibly regarded as a specialised Trochosphere, is the genus *Dinophilus*, with the nature of which advanced students should make themselves acquainted.

At this stage I may also mention that there are several sets of small worm-like animals of which we know very little. It is quite possible that some of them may become of great interest to the systematic zoologist, but we do not yet understand what places in the system they should occupy. Moreover, as they are small, unfamiliar, and unknown to myself, I shall simply refer the curious to what more complete works say about the Gasterotricha, Echinoderidæ, Desmoscolecidæ, and Chætoderidæ.

FIFTH SERIES OF "WORMS"—FOUR CLASSES.

Provisionally ranked together (by Lang) as Prosopygii.

Class SIPUNCULOIDEA, *e.g.*, *Sipunculus*.

Marine worms usually living in the sand. The body is elongated, and apparently unsegmented. The oral or anterior region can be invaginated

by special muscles. There are no setæ, hence the animals are sometimes, but perhaps erroneously, classified as Gephyrea Achæta. The nervous system consists of an œsophageal ring, and a median ventral nerve-cord, which shows slight hints of segmentation. There is a spacious body-cavity.

SIPUNCULIDÆ.	PRIAPULIDÆ.
The anus is dorsal and anterior, and the food canal is usually in a spiral; the mouth is surrounded by tentacles. There is a closed vascular system, with branches to the tentacles. An anterior pair of nephridia serve also as genital ducts, removing the reproductive cells from the body-cavity. The sexes are separate. Examples—*Sipunculus*. *Phascolosoma*.	The alimentary canal is straight or slightly looped, and the anus is dorsal and posterior. There are no tentacles. There is no vascular system. No anterior nephridia, but a pair of tubes open beside the anus, and are said to be excretory in the young, genital in the adult. The sexes are separate. Examples—*Priapulus*. *Halicryptus*.

Class PHORONIDEA. *Phoronis*.

This type is represented by one genus, *Phoronis*, a worm-like marine animal enclosed in a fixed leathery tube. Numbers occur together. The mouth is surrounded by numerous ciliated tentacles. These have a sort of internal skeleton, and are disposed on a horse-shoe-shaped base. The alimentary canal is curved, and ends dorsally near the mouth. The nervous system lies in the ectoderm, and consists of a ring around the mouth, and of a cord down the left side of the body. Two ciliated sensory pits lie beside the anus. The body-cavity is well-developed. There is a closed vascular system with nucleated red cells. Two ciliated nephridia, opening posteriorly, serve also as genital ducts. *Phoronis* is hermaphrodite. The peculiar larva, known as an *Actinotrocha*, undergoes metamorphosis.

Class POLYZOA OR BRYOZOA. Sea-Mats, etc.

Small animals which (with one exception) form colonies. The body is surrounded by a cuticle, which is usually very firm posteriorly. The alimentary canal is curved so that it ends near the mouth. Numerous tentacles surround the mouth, and are often disposed on a horse-shoe-shaped base. The nervous system is represented by a ganglion between mouth and anus. There is no vascular system. If nephridia are present, they are two in number, opening near the mouth, and are not used as genital ducts. All the Polyzoa form buds. The larva is free-swimming.

ECTOPROCTA.	ENDOPROCTA.
Anal opening outside the basis of the tentacles. Never stalked. A spacious body-cavity. (*a*) Tentacles in a crescent. Freshwater, *Cristatella*, *Lophopus*. etc. (*b*) Tentacles in a circle. Marine, except *Paludicella*. *Flustra*, the common sea-mat; *Membranipora*, encrusting seaweed, etc.; *Cellepora*, very calcareous; *Alcyonidium*, gelatinous.	Anal opening within the basis of the tentacles. The body is stalked. No body-cavity. A pair of nephridia. Hermaphrodite. *Pedicellina*, forming colonies as usual. *Loxosoma*, solitary. Both are marine.

Class BRACHIOPODA. Lamp-shells.

The Brachiopods are quaint marine animals which were once very numerous, but are now decadent. The body is enveloped *dorsally and ventrally* by two folds of skin or mantle, which secrete a shell usually of lime, but sometimes "horny." There is no real resemblance between a Brachiopod shell and that of a bivalve Mollusc, except that both consist of two valves. In Brachiopods these lie dorsally and ventrally, in Lamellibranchs they are lateral; moreover, in Brachiopods the ventral valve is usually the larger. It is hardly necessary to say that the Brachiopod organism is not the least like a Mollusc.

From the mouth region arise ciliated tentacles, or two long "arms" coiled in a spiral and often supported by a calcareous skeleton. The ciliated food-canal ends blindly, or near the mouth, except in *Crania* where it is posterior and dorsal. There is a nerve-ring round the gullet with a slight brain and inferior ganglion. Sensory structures, in many cases, perforate the valves. It is probable that a heart lies above the gut, and is connected with blood vessels. Two (or more rarely four) nephridia open near the mouth, and serve also as genital ducts. The posterior region of the body often forms a stalk by which the shell is moored, but in many the stalk is absent, and the animal is directly attached to the substratum. The sexes are sometimes separate, but perhaps some are hermaphrodite. There is a metamorphosis in the development, of which however little is known.

TESTICARDINES.	ECARDINES.
The valves are hinged. There is no anus. *Terebratula*. *Waldheimia*.	There is no hinge. There is an anus. *Crania*. *Lingula*, persistent since Palæozoic ages.

CHAPTER XII.

ECHINODERMATA.

Classes.
1. HOLOTHUROIDEA. Sea-Cucumbers.
2. ECHINOIDEA. Sea-Urchins.
3. ASTEROIDEA. Starfishes.
4. OPHIUROIDEA. Brittle-stars.
5. CRINOIDEA. Feather-stars.
6. BLASTOIDEA. Extinct.
7. CYSTOIDEA. Extinct.

THE Echinodermata include seven classes, of which two are wholly extinct.

HOLOTHUROIDEA.
Sea-cucumbers.
(Scytodermata.)

ECHINOIDEA.	ASTEROIDEA.	OPHIUROIDEA.
Sea-urchins.	Starfish.	Brittle-Stars.

(Echinozoa.)

CRINOIDEA, and the extinct BLASTOIDEA and CYSTOIDEA.
Feather-Stars.
(Pelmatozoa.)

General Characters of Echinodermata.

The Echinoderms are marine, and feed on organic débris, or, less frequently, on living animals.

The adults are radially, the larvæ bilaterally, symmetrical.

Lime is deposited in the mesodermic portion of the skin, and often of other parts.

A peculiar system, known as the water-vascular, attains great development, and has respiratory or locomotor functions. It is not unlikely that this peculiar system originally had an excretory significance, nor does it seem to have entirely lost this function. The main branches of this system, and the nerves and blood-vessels as well, exhibit in the majority a five-rayed stellate arrangement.

There is a remarkable metamorphosis in development.

Most Echinoderms have the power of casting off and regenerating parts of their body.

The average habit is sluggish.

General Survey.—Hæckel compared an ordinary five-armed starfish to a colony of five worms joined by their heads. Each arm is anatomically complete in itself, with ventral nerve, terminal eye, blood-vessel, water-vessel, digestive cæca, and reproductive organs. There is also a certain independence of life, for an arm cut off can grow the other four. The peculiar life-history was regarded by Hæckel as an illustration of alternation of generations. A larva, equivalent to one worm, gave origin by budding to a second stage equivalent to five. Beginning with an ancestral star-fish (*Pentastræa*), Hæckel interpreted the brittle-stars and feather-stars as modifications of this, while he believed that in another direction centralisation had resulted in the sea-urchins, and in the yet more aberrant sea-cucumbers.

Now, however, the prevalent view is very different. The embryologists do not accept the "five worm theory," nor do they regard the metamorphosis as an alternation of generations. The Holothurians are supposed to be, in form at least, nearest to the worm-like ancestor, and the interpretation which regards the five-armed starfish as a decentralisation of a flattened sea-urchin is more plausible than that which regards the sea-urchin as the concentration of a puffed-up starfish.

But without discussing speculations in regard to the hypothetical worm-like ancestors of all Echinoderms, without departing from forms which we know, we may state the following generally accepted conclusions:—(*a*) The Holo-

thuroids are nearer to the Echinoids than to any of the others. (*b*) The Echinoids are linked by transition types to the extinct cystoids. (*c*) There are direct affinities between Echinoids and Asteroids, and this further connection that the Asteroids are linked to the Cystoids. (*d*) The Ophiuroids are very closely allied to the Asteroids, if indeed the two sets do not form one class. (*e*) The Blastoids and Crinoids are related to one another, and also to the Cystoids, which thus form a central class.

In our survey of the classes, we shall begin with the star-fish-like forms which are perhaps most familiar; with these the brittle-stars will be briefly contrasted; we shall then describe the sea-urchins and sea-cucumbers, and finish with the Crinoids. The general characters of each class may be read from the synoptic table at the end.

Class ASTEROIDEA. STARFISH.

The description applies especially to *Asterias* or *Aster-acanthion rubens*.

Form.—The common five-rayed starfish (*Asterias* or *Asteracanthion rubens*) is sometimes seen in shore pools exposed at low water, but its haunts are on the floor of the sea at greater depths. There it moves about sluggishly in any direction by means of the tube-feet of the water-vascular system, to be afterwards described. Each arm bears a deep ventral groove in which the tube-feet are lodged. The mouth is in the middle of the ventral surface, the food-canal ends about the centre of the dorsal disc. With this flat, five-rayed form, the 11–13 rayed sun-star (*Solaster*), the pincushion-like *Goniaster*, and the pentagonal pancake-like *Palmipes*, should be contrasted.

Integument.—(*a*) The body is covered by a ciliated ectoderm. This includes supporting, glandular, and sensory cells, and beneath it there is a network of nerve fibrils with ganglionic cells.

(*b*) The mesodermic part of the integument consists of two layers with irregular channels between them. In the outer of these layers are formed all the limy structures, except one set (the ambulacral ossicles),

which are formed by the inner layer. Between two of the arms lies a conspicuous calcareous tubercle or madreporic plate,—a porous sieve through which fluid enters and leaves the water-vascular system. The two rays enclosing this madreporic plate are called the *bivium*; the other three form the *trivium*.

The Calcareous Skeleton is intricate. We shall mention only the more important components,—the plates forming the ventral groove of each arm, the small scattered plates, the short spines and the pedicellariæ.

(*a*) In association with the inner mesodermic layer of the integument, there is developed on the ventral surface of each arm a double series of sloping plates. These two series meet dorsally, like rafters, in the middle line of the arm, forming an elongated shed. The rafter-like plates are called *ambulacral ossicles*; the groove which they bound lodges the nerve-cord, the blood-vessel, the water-vessel, and the tube-feet of each arm.

(*b*) In association with the outer mesodermic layer of the integument numerous smaller plates are developed, *e.g.*, the *adambulacrals* which articulate with the outer lower ends of the ambulacrals. The dorsal surface bears a network of little ossicles, and many of these bear spines. Peculiarly modified spines, known as *pedicellariæ*, look like snapping scissor blades mounted on a single soft handle. "They are used to take hold of objects such as Algæ, until the tube-feet can be applied."

Muscular System.—A starfish is not very muscular, but it often bends its arms upwards, and may sometimes be seen tightly embracing an oyster. Other muscles affect the size of the ventral grooves, and muscular elements also occur on the protrusible part of the stomach, and in connection with the water-vascular system.

Nervous System.—Underneath the ciliated ectoderm lies a network of nerve fibrils, with some ganglionic cells. But these diffuse elements are concentrated in a pentagon around the mouth, and a nerve along each arm. The system is not separable from the skin.

Sense-Organs.—A red "eye," sensitive to light, lies at the

tip of each arm, and is usually upturned. It consists of numerous little cups, lined by sensitive and pigmented cells, containing clear fluid, covered by the cuticle. The skin is diffusely sensitive.

Alimentary System.—The starfish is fond of young oysters and other bivalves, and may be found with part of its stomach extruded over them. This protrusible or "cardiac" portion the stomach, which bulges slightly towards the arms is followed by an upper or pyloric portion, giving off five branches, each of which divides into two large digestive cæca for each arm. These glands contain a yellowish pigment (enterochlorophyll) and secrete tryptic, peptic, and diastatic ferments. From the short tubular intestine between the stomach and the central dorsal anus two little outgrowths are given off, which are believed to be homologous with the "respiratory trees" of Holothuroids. Some parts of the food-canal are ciliated.

Body-Cavity.—The cœlome is distinct, though not much of it is left unoccupied either in the disc or in the arms. It is lined by ciliated epithelium, and the fluid in the cavity contains a few brownish amœboid cells, the pigment of which probably aids in respiration.

Water-Vascular System.—When we watch a starfish crawling up the side of a rock we see that scores of tube-feet are protruded from the ventral groove of each arm, that these become long and tense, and that their sucker-like terminal discs are pressed against the hard surface. There they are fixed, and towards them the starfish is gently lifted. The protrusion is effected by the internal injection of fluid into the tube-feet; the fixing is due to the fact that the subsequent withdrawal of the water produces a vacuum between the ends of the tube-feet and the surface of the rock.

But it is necessary to inquire into the course of the fluid. It is most convenient to begin with the madreporic plate lying between the bases of two of the arms (the bivium). This plate is a complex calcareous sieve, with numerous perforating canals and external pores. It may be compared to-the rose of a watering-pan, but the holes are much more numerous and lead into small canals which gradually converge into a main canal. The latter runs down through the

body, and is like a complex calcareous filter. It is called the stone-canal.

The stone-canal leads into a water-ring round about the mouth. From this circumoral ring are given off nine transparent vesicles, and five radial tubes, one for each of the arms. Considerations of symmetry suggest that there should be ten transparent vesicles, but the stone-canal has taken the place of one.

Along each arm, then, there runs a radial vessel. It lies in the ambulacral groove beneath the shelter of the rafter-like ossicles. From it branches are given off to the bases of the tube-feet, but from each of these bases a canal ascends between each pair of ambulacral ossicles, and expands into an ampulla or reservoir on the dorsal or more internal side. The fluid in the system may pass from the radial vessels into the tube-feet, and from the tube-feet it can flow back, not into the radial vessel, but into the ampullæ. There are muscles on the walls of the tube-feet, ampullæ, and vessels. At the end of each arm there is a long unpaired tube-foot, which seems to act as a tactile tentacle.

To recapitulate, the madreporic plate leads into the stone-canal, this passes into the ring round the mouth with its nine vesicles, from the ring radial vessels run along the arms, they give off branches to the tube-feet, and the bases of the tube-foot communicate with the ampullæ.

This water-vascular system is in many ways difficult to understand, but the questions involved are hardly within the province of an elementary manual. It develops from one of the body-cavity pouches (see p. 221), but to what in other animals does it correspond? May it be an excretory system which has taken on other functions, and has it still some excretory significance? It is certainly for the most part locomotor in Starfishes, but may it not help also in respiration, which seems to be its function in Brittle-Stars and Crinoids?

Vascular System.—By the side of the stone-canal, enclosed in a space which is probably part of the body-cavity, lie numerous blood-vessels. They form an imperfectly understood structure called the "heart" or "plexiform organ," and are connected dorsally with a vascular ring round the anus, and ventrally with another round the mouth. From

the ring round the anus, vessels are given off to the reproductive organs and to the intestine; from the ring round the mouth, a radial vessel runs along the groove of each arm, below the water-vessel and above the nerve. The fluid in the blood-vessels contains brown cells, a few of which also occur in the water-vascular system.

Respiratory System.—From the dorsal surface and sides of a starfish in a pool, you will see numerous transparent processes hanging out into the water. They are the simplest possible respiratory structures, contractile outgrowths of the skin, with cavities continuous with the cœlome, and are called "skin-gills." It is likely that the brown cells of the body-cavity fluid act like rudimentary red blood-corpuscles; the water-vascular system may help in aëration; and the whole body is of course continually washed with water.

Excretory System.—It may be that the water-vascular system has a slight excretory function; it may also be that excretion is somehow concerned in forming the carbonate of lime skeleton, but facts are wanting.

Reproductive System.—The sexes are separate, and they are like one another, both externally and internally. The organs develop periodically, and lie in pairs in each arm. Each is branched like an elongated bunch of grapes, and is surrounded by a blood sinus. Each has a separate duct, which opens on a porous plate, between the bases of the arms on the dorsal surface. The eggs are fertilised in the water, and the free-swimming larva, which will be described along with those of the other classes, is known as a *Bipinnaria* or as a *Brachiolaria*.

Other Starfishes.

All Asteroidea are not of course exactly like the common type which we have described; thus *Astropecten* and most forms related to it have blind food-canals; *Brisinga* has long arms, arising abruptly from a small disc as in Brittle-Stars, and has no ampullæ; *Luidia* has three-bladed pedicellariæ; in most forms the genital ducts end on plates with a single aperture, and so on. But as such differences are not important for our present purpose, we shall simply notice a few of the interesting forms.

The commonest European forms are species of *Asterias* or *Asteracanthion*, *Astropecten*, *Cribrella*, *Solaster*, *Goniaster*.

DIAGRAM XI.

ECHINODERMS.

The figure named *Aster*, is a cross section of a starfish arm, showing the external ectoderm, the calcareous plates (very dark), one of the small spines (*sp.*), a skin-gill (*sk.g.*), the ambulacral ossicles (*amb. oss.*), the radial nerve (*n.*), the radial blood-vessel (*b.v.*), the radial water-vessel (*r.c.*), a tube-foot (*t.f.*), an ampulla (*amp.*), sections of the digestive cæca (*d.c.*), and of the reproductive organs (*rep.*). (In part after Ludwig.)

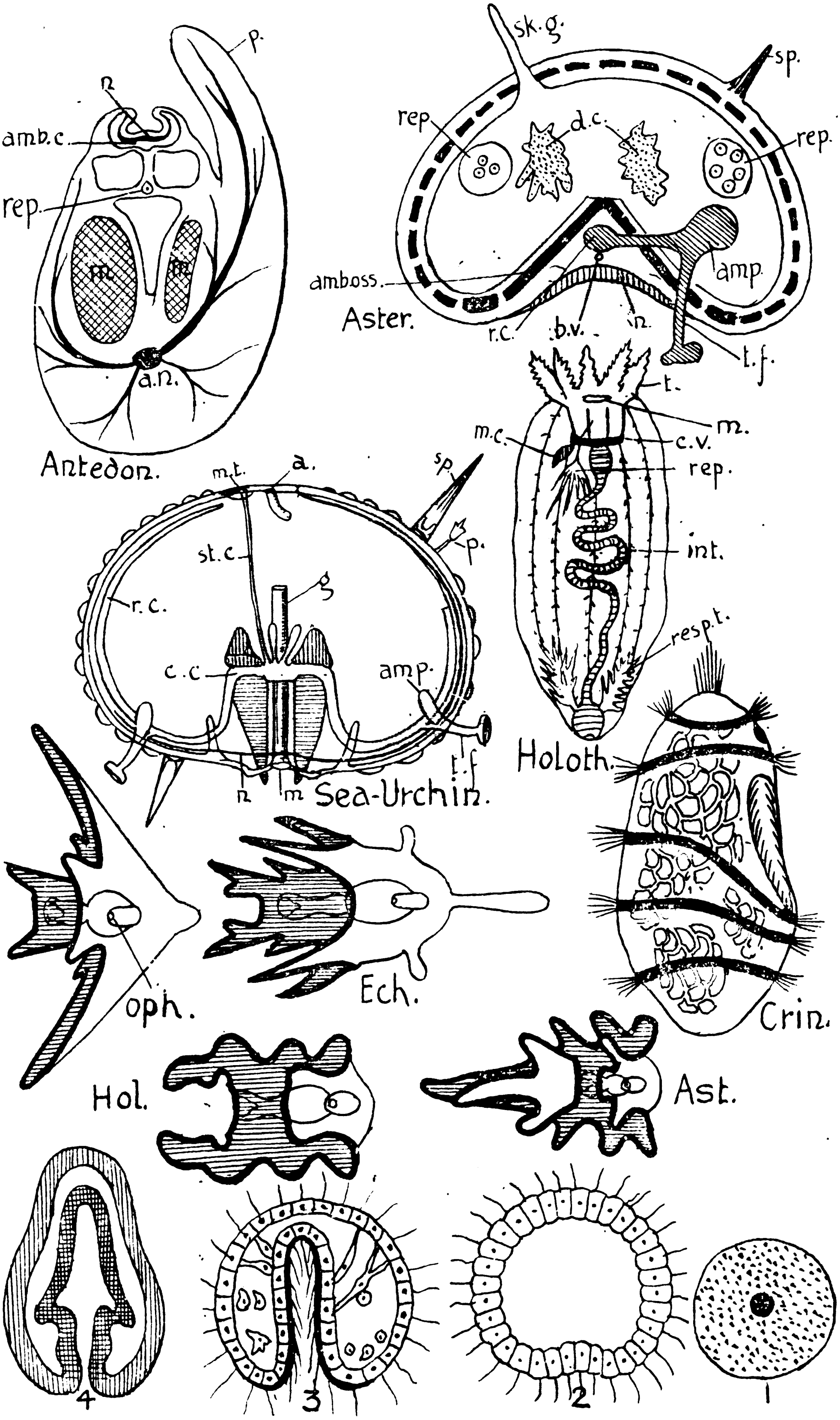
The figure named *Antedon* is a cross section (after Marshall), of one of the arms of that Crinoid. It shows a section of a pinnule (*p.*), the ambulacral nerve (*n*), the antambulacral nerve (*a. n.*), the ambulacral water-vessel (*amb. c.*), the position of the reproductive strand (*rep.*), the muscles of the arm (*m.*), and the cœlomic spaces. Below *Antedon* is a vertical section of a Sea-urchin (after Huxley). At *m.* is the mouth, *n.* is the nerve, *c.c.* the circular water-vessel around the top of Aristotle's lantern, *g.* the gut, *st. c.* the stone-canal, *r.c.* a radial water-vessel, *amp.* an ampulla, *t.f.* a tube-foot, *p.* a pedicellaria, *sp.* a spine, *a.* the anus, *m.t.* the madreporic tubercle.

To the right is a section of a Holothurian, showing the tentacles (*t.*), the mouth (*m.*), the circumoral water-vessel (*c.v.*), the madreporic or stone-canal (*m.c.*), the reproductive organs (*rep.*), the intestine (*int.*), the respiratory trees (*resp. t.*), rising from the cloaca, and the five lines of longitudinal muscles.

At the foot of the page is a ripe ovum (1), a section of a blastosphere (2), a section of a gastrula (3) with mesenchyme cells, and a section (4), showing the origin of two cœlome pouches from the archenteron.

Above are five larval forms :—*Hol.*, the *Auricularia* of a Holothurian ; *Ast.*, the *Bipinnaria* of a starfish ; *Oph.*, the *Pluteus* of an Ophiuroid ; *Ech.*, the *Pluteus* of an Echinoid ; *Crin.*, the larva of *Antedon*, with ciliated bands, and with calcareous plates forming within it. The ciliated bands are indicated by the dark lines. (From Balfour.)

Echinoderms.



The largest are such as *Asterias gigantea* (from the Pacific coast of N. America), measuring 2 feet in diameter, or *Pycnopodia helianthoides*, about a yard in diameter, and with over twenty arms.

There are many deep-sea forms, such as the ophiuroid-like *Brisinga*, the widely distributed *Hymenaster*, and the blue *Porcellenaster cœruleus*, but the majority occur in water of no great depth.

In connection with external form, the many-rayed *Solaster*, the pin-cushion-like *Goniaster*, the pentagonal pancake-like *Palmipes*, should be considered.

Parental care is incipient among Asteroids, for a large *Asterias* has been seen sheltering its young within its arms; there is a definite brood pouch in the form of a sort of tent on the dorsal surface of *Pteraster*, and there are other arrangements which serve a similar purpose.

Many Asteroids break very readily, or throw off their arms when these are seized. Professor Forbes describes how a fine specimen of *Luidia* thus escaping him gave a wink of derision as it passed over the side of the boat. The lost parts are slowly regenerated, and strange forms are often found in process of regrowth. Thus the "comet-form" of starfish occurs when a separated arm proceeds to grow the other four. Asteroidea occur in Silurian strata.

Class OPHIUROIDEA. BRITTLE-STARS.

The body of a brittle-star differs from that of a starfish in the abruptness with which the arms spring from the central disc. These arms are muscular, and useful in wriggling and clambering; they do not contain outgrowths of the gut, nor reproductive organs. Moreover there is no ambulacral groove, and the tube-feet which project on the sides are too small to be of locomotor service. The madreporic plate is situated on the ventral surface, usually on one of the plates around the mouth. The food-canal ends blindly.

The reproductive organs lie in pairs between the arms, and open into pockets or bursæ formed from inturnings of the skin. The slits by which these bursæ open are evident at the bases of the arms. Water currents pass in and out, perhaps aiding in respiration.

The free-swimming larva is a *Pluteus*, very like that of the Echinoids.

Ophiuroids are first found in Silurian strata.

1. Euryalida. Skin without plates, arms simple or branched and capable of being rolled up.

   Astrophyton. Gorgonocephalus.

2. Ophiurida. Skin with plates, arms simple.
Ophiocoma, *Ophiothrix*, are common genera.
Amphiura squamata is said to be hermaphrodite.

Class Echinoidea. Sea-Urchins.

Types—*Echinus edulis*, *Strongylocentrotus lividus*, *etc.*

Most sea-urchins live off rocky coasts, and not a few shelter themselves sluggishly in holes. They move by means of their tube-feet and spines, and seem to feed on sea-weeds, and on the organic matter found in mud and other deposits. After the perils of youth are past, the larger forms have few formidable enemies.

Form, skin, and skeleton.—The hard and prickly body is a flattened sphere. The food-canal begins in the middle of the lower surface; it ends at the opposite pole in the middle of an apical disc formed of a central plate surrounded by five "ocular" and five "genital" plates. The ocular or radial plates bear eye-specks; the genital or basal plates bear the apertures of the genital ducts, but one of the five is modified as the madreporic plate. From pole to pole run ten meridians of calcareous plates which fit one another firmly; five of these (in a line with the ocular plates) are known as "ambulacral areas," for through their plates the locomotor tube-feet are extruded; the five others (in a line with the genital plates) are called inter-ambulacral areas, and bear spines, not tube-feet. Altogether, therefore, there are ten meridians, and each meridian-area has a double row of plates. On the dry shell from which the spines have been scraped, the ambulacral plates are seen to be perforated by small pores, four pairs or so to each plate. Through each pore a tube-foot is connected with an internal ampulla. In the starfish the ambulacral areas are wholly ventral, and the apical area seen on the dorsal surface of the young forms is not demonstrable in the adult.

The "posterior" ambulacra, those between which the modified basal or madreporic plate lies, are often distin-

guished as the "bivium," the other three form the "trivium," and the middle one of the three is "anterior."

On the shell there are obviously many spines, most abundant on the inter-ambulacral areas. Their bases fit over ball-like knobs, and are moved upon these by muscles. But besides these, there are two modified forms of spines,—the minute pedicellariæ, with three snapping blades on a soft stalk, and small globular sphæridia, which contain many nervous cells, and show by their motions that they detect chemical changes in the water.

In front of the mouth project the tips of five teeth, which move against one another, grasping and grinding small particles. They are fixed in five large sockets, and along with fifteen other pieces form "Aristotle's lantern," a complex masticating apparatus, of whose history we know little. It surrounds the pharynx, and is swayed about and otherwise moved by muscles, many of which are attached to five beams which project inward from the margin of the shell round about the mouth.

As in other Echinoderms, the skeleton of lime is mesodermic. The shell is covered externally by a delicate ciliated ectoderm, beneath which, in a thin layer of connective tissue, there is a network of nerve-fibres, and some ganglion-cells. Internally, there is another thin layer of connective tissue, and a ciliated epithelium lining the body-cavity. The skeleton grows by the formation of new plates, and also by the individual increase of each. In a few forms the shell retains some plasticity.

The Nervous System consists of a ring around the mouth, of radial branches running up each ambulacral area, and of the superficial network. Tube-feet, sphæridia, pedicellariæ, and spines are all under nervous control, and each radial nerve ends in the "eye-specks" of the apical "ocular plates." It is probable that all the tube-feet are sensory, and this is certainly the main function of ten which adjoin the mouth.

The Alimentary Canal passes through Aristotle's lantern, and the intestinal portion lies in two and a half coils around the inside of the shell to which it is moored by mesenteries. It contains fine gravel, sand, and some organic débris. It ends near the centre of the apical disc, whence the pedicellariæ have been seen removing the fæces. On the inner wall of the

gut, within the first coil, there lies a canal or "siphon," open at both ends. Its import is unknown. The spacious body-cavity is lined by ciliated epithelium and contains a "perivisceral" fluid, whose corpuscles seem to have a respiratory brown pigment. When the fluid of a perfectly fresh Sea-urchin is emptied out, the contained corpuscles are said to unite in plasmodia, forming composite amœboid clots.

The Water-Vascular System.—The madreporic plate communicates with a membranous stone-canal, which goes vertically through the body, and leads into a circular vessel near the upper end of the lantern. This gives off five inter-radial transparent vesicles, and five radial vessels which extend down the sides of the lantern and up each ambulacral area. Finally, each radial vessel gives off numerous lateral branches, which communicate with the internal ampullæ and the external tube-feet. When the tube-feet are made tense with fluid, they extend beyond the limit of the spines, and are attached to the surface of the rock over which the sea-urchin slowly drags itself. The sucker at the tip of each tube-foot bears small calcareous plates regularly arranged, indeed there is hardly any part of an Echinoderm in which lime may not be deposited. Before bending upwards from the base of the lantern, each radial vessel gives off a branch to two large tentacle-like tube-feet without attaching discs. They lie round about the mouth, and are sensitive.

The Blood-Vascular System is not readily traced, and there is uncertainty as to its precise nature. Alongside the stone-canal there lies an enigmatical structure, to which such names as "plexiform organ," "ovoid gland," "dorsal organ," and "heart" are given. It is connected superiorly with the five genital organs, inferiorly with a circular vessel surrounding the pharynx at the top of the lantern, within and beneath the water-ring. This vascular ring seems to be connected, by branches at least, with the five pockets of the water-ring to which the name "Polian vesicles" has been mistakenly applied. A distinct vessel arises from the ring and runs along the inner or ventral surface of the intestine, while another on the opposite side seems to originate from capillaries. It is likely enough that there may be radial

blood vessels or spaces in the ambulacral areas. The fluid contains corpuscles, some of which have brown pigment.

Respiratory and Excretory Systems.—On the area round about the mouth there are ten hollow outgrowths, which resemble the skin-gills of starfishes, and have probably a similar function. As already mentioned, the pigmented cells of the body-cavity fluid seem able to absorb oxygen. The observation that currents pass out of the madreporic plate, suggests that the water-vascular system has in part an excretory function.

Reproductive System.—The sexes are separate, and like one another. Five branched yellow-brown ovaries or rose-white testes lie interradially under the apex of the shell, and open by separate ducts on the five genital or basal plates. In spring the apical disc may be seen covered with orange ova or milky-white spermatozoa. At this season in the south of Europe the sea-urchins are brought to market.

The eggs are fertilised externally by sperms wafted from adjacent sea-urchins, and the free-swimming larva, which we shall afterwards describe, is called a Pluteus.

Classification of Echinoidea.

1. Palæo-echinoidea. Extinct forms, apparently with a plastic test, of over-lapping and variable plates. They appear in Lower Silurian Rocks.

2. Desmosticha. Regular and symmetrical sea-urchins like *Echinus*.
   e.g., *Cidaris*, without external gills.
   Diadema, a species has been described as covered with compound eyes.
   Cyanosoma urens, the spines contain a poison apparatus.
   Echinothuridæ have flexible tests.

3. Clypeastroidea. Shield-shaped, and often flat. The food-canal ends outside the apical disc on the posterior inter-radius (exocyclic).
   e.g., *Clypeaster*.

4. Petalosticha. Heart-shaped. The mouth is ex-centric, the food-canal ends away from the apical disc. There are no masticating organs. On the dorsal surface the ambulacral areas dilate from the apex outwards, and contract again towards the margin in the form of "petals." The anterior area is often different from the other four.
   e.g., *Spatangus*.
   Hemiaster and some others carry their young among their spines.

Class Holothuroidea. Sea-Cucumbers.

The Holothurians do not at first sight suggest the other Echinoderms, for they are like plump worms, and the calcareous skeleton is not prominent. But closer examination shows the characteristic pentamerous symmetry, and the occurrence of calcareous plates in the skin. We may think of a sea-urchin as a hardened Holothurian, or of a Holothurian as a soft sea-urchin with its mouth surrounded by tentacles.

They occur in almost all seas, from inconsiderable to very great depths. Their food consists of small animals, and of organic particles from the sand. Some of them grasp little things in their waving tentacles, and then plunge these into the pharynx. The muscles of a captured Holothurian often over-contract and eject the viscera at the ends or through a side rupture; in this way the animal may sometimes escape, and the viscera can be regrown at leisure.

The worm-like body is often regular in form, with five equidistant longitudinal bands along which tube-feet emerge. But three of these "ambulacral areas" are often approximated on a flattened ventral sole, leaving two on the convex dorsal surface, and there are other modifications of form.

The walls of the body are tough and muscular, and the skeleton is represented by scales, plates, wheels, and anchors of lime scattered in the skin, by plates around the gullet, and on a few other regions.

The nervous system consists of a circumoral ring in which the five radial nerves running in the ambulacral areas unite, and from which the nerves to the tentacles arise. Sense organs are represented by the tentacles, which sometimes have "ear-sacs" at their bases, and by tactile processes on the dorsal surface of some of the creeping forms.

From the terminal or ventral mouth, surrounded by five, ten, or more tentacles, the food-canal coils to the opposite pole. There it expands into a chamber sometimes contractile, and from this are given off in many forms a pair of much branched "respiratory trees," which extend forward in the body-cavity. These are homologous with the anal

glands of the starfish, and their title seems for the most part incorrect. Also connected with the cloaca are little processes—called Cuvierian organs—which the irritated Holothurian ejects.

The water-vascular system may consist of a ring around the mouth communicating (*a*) with the tentacles, (*b*) with five radial vessels, one for each ambulacral area, (*c*) with a "Polian vesicle" or more than one of these reservoirs pendent in the body-cavity, (*d*) with a "stone canal" also hanging in the body-cavity, or opening on the skin. The radial vessels may have ampullæ and tube-feet as in sea-urchins. But there are many divergences, especially in the reduction of the tube-feet areas. Instead of tube-feet, or along with them, there are often conical processes or papillæ without terminal discs. These are especially common on the dorsal surface. The blood-vascular system is not very definite, and seems to consist mainly of spaces in the connective tissue.

The sexes are usually separate. The reproductive organs are branched tubes which open within or just outside the circle of tentacles. They and other internal organs of Holothurians are often very brightly coloured. The larva is, in most cases, what we shall afterwards describe as an *Auricularia*, and the development is, as in other Echinoderms, very indirect. Sometimes, however, the larval stage is skipped, as in *Cucumaria crocea*, which carries its young among its dorsal tube-feet, or in *Psolus ephippiger*, which has a dorsal brood-pouch strengthened by special plates.

The calcareous plates of Holothurians are found as far back as Carboniferous strata. Trepang or *Bêche-de-mer* is a Chinese delicacy consisting of dried Holothurians.

Classification.

1. Elasipoda: primitive deep-sea forms, bilaterally symmetrical, with tube-feet on the ventral surface only, and with papillæ on the back.
   The stone-canal often opens externally by a pore.
   There are no respiratory trees.
   e.g., *Kolga*, *Elpidia*.

2. Pedata: with well-developed tube-feet and papillæ.
   e.g., *Holothuria*, *Cucumaria*, *Psolus*.

3. Apoda : without tube-feet or papillæ.
e.g., *Synapta*, a remarkable animal especially apt to break in pieces, without even radial water-vessels, without respiratory trees or Cuvierian organs; hermaphrodite; with beautiful calcareous anchors and plates in the skin.

Semper has described a strange animal, *Rhopalodina lageniformis*, from the Congo coast. It is like a very globular flask, with mouth and anus close together at the narrow end, with ten ambulacral areas.

Class Crinoidea. Feather-Stars.

Commonest Type, *Antedon rosacea*, The Rosy Feather-star.

The feather-stars or sea-lilies differ from other Echinoderms in being fixed permanently or temporarily by a jointed stalk. The modern Comatulids, *e.g.*, the rosy feather-star (*Comatula* or *Antedon rosacea*) leave their stalk at a certain stage in life; but the others, *e.g.*, *Pentacrinus*, are permanently stalked like almost all the extinct stone lilies or encrinites once so abundant. Most of them live in deep water, and many in the great abysses. An anchorage is found on rocks and stones, or in the soft mud, and great numbers grow together—a bed of sea-lilies. The free Comatulids swim about by bending and straightening their arms, and they have grappling "cirri" on the aboral side, where the relinquished stalk was attached. By these cirri they moor themselves temporarily. Small organisms—Diatoms, Protozoa, minute Crustaceans—are wafted down ciliated grooves on the arms to the central mouth, which is of course on the upturned surface. Some members of the class, *e.g.*, *Comatula*, are infested by minute parasitic "worms" (*Myzostoma*) allied to Chætopods, which form galls on the arms. A lost arm can be replaced, and even the visceral mass may be renewed.

The animal consists of (1) a cup or calyx, (2) an oral disc forming the lid of this cup, (3) the radiating "arms," and (4) the stalk supporting the whole.

The calyx consists of apical plates (corresponding to the apical plates of the sea-urchin), to which radials belonging to the arms and other accessory plates are often added. In a few extinct genera with no stalk the dorso-central plate has

its normal position, in the others it is at the anchoring base of the stalk. When Comatulids break off from their larval stalk they carry with them the topmost joint, which becomes the central part of their calyx.

The oral disc, turned upwards, is supported by plates. Here the anus also is situated. The arms usually branch in dichotomous fashion, and thus ten, twenty, or more may arise from the original five. But the growing point continues to fork dichotomously, like the leaf of many ferns, and as each alternate fork remains short, a double series of lateral "pinnules" results. The arms are supported by calcareous plates. The stalk usually consists of numerous joints, especially in extinct forms, in some of which it measured fifty and even seventy feet in length. Except in *Holopus*, and in the stalked stage of *Antedon*, the stalk bears lateral cirri.

The nervous system is remarkable in being double. On the upturned surface of each arm, beneath the food-wafting ciliated grooves, there is a *motor* ambulacral or radial nerve. These are united in a ring or plexus around the mouth. So far, the Crinoid is like a starfish. But on the opposite surface, there is an antambulacral *motor and sensory* nervous system consisting of a central mass, with branches to the cirri, and to the arms. Apart from the superficial epithelium there are no sensory structures.

The ciliated food-canal descends from the mouth into the cup, and curves up again to the anus which is usually ex-centric in position. From the cup, where the body-cavity is in great part filled with connective tissue and organs, two cœlomic canals extend into each of the arms. One of these—called subtentacular—lies just beneath the radial water-vessel; the other—called cœliac—is more internal, but still ventral. They communicate at the apices of the arms and pinnules, and currents pass up the subtentacular and down the cœliac canal.

The blood-vascular system consists of a circumoral ring which is connected with a radial vessel under each ambulacral nerve, and with a circumœsophageal plexus. There is also a "plexiform organ," "lying interradially in the disc anteriorly to the mouth," with many connections with the above-mentioned plexus, with the vessels to the organs, and with a strange "chambered organ" which lies within the central aboral nervous system, and gives off vessels to the stalk and

cirri. But this nervous-vascular structure is much too intricate to be described here.

The water-vascular system consists as usual of a circumoral ring and radial vessels. These lie under the corresponding blood-vascular system. But the system is divergent in several ways; (*a*) water passes into it by several ciliated and branched water-tubes which hang from the ring, and from the origins of the radial vessels, into the body-cavity; (*b*) water passes from the exterior into the body-cavity by numerous (1500 on the disc of *Antedon rosacea*) ciliated water-pores which pierce the disc, and sometimes the arms also; (*c*) "the radial water-vascular vessels give off alternately to the right and left, in groups of three each, delicate tubular branches, respiratory in function, which form the tentacles homologous with tube-feet."

The sexes are separate, and a process resembling sexual intertwining has been observed in *Antedon*. The reproductive organs extend as tubular strands from the disc along the arms, but are rarely functional except in the pinnules, from each of which the elements burst out by one duct in females, in males by one or two fine canals.

There are about 400 living species in twelve genera, but about 1500 species in 200 genera are known from the rocks. The class is obviously decadent. It is represented in the Cambrian, and attained its maximum development in Silurian, Devonian, and Carboniferous times.

The oval ciliated larva of *Antedon*, the only one known, is less quaint than that of other Echinoderms.

The Crinoids are more nearly related to the extinct Cystoids and Blastoids than to the other classes.

Classification of Crinoidea.

1. Palæo-crinoidea (= Tesselata). Palæozoic forms. The symmetry of the calyx is not always pentamerous.

2. Neo-crinoidea (= Articulata + *Holopus* and *Marsupites*).
   Mesozoic and recent. The calyx always has pentamerous symmetry. The recent forms include the stalked *Pentacrinus*, *Rhizocrinus*, *etc.*, and the free Comatulids, which pass through a stalked *Pentacrinus* stage, *e.g.*, *Antedon*.
   Holopus is a remarkable deep-sea form with direct ancestors in the Upper Silurian. *Marsupites* is an extinct Crinoid which has no stalk.

Class BLASTOIDEA. Wholly extinct.

The Blastoids are first found in the Upper Silurian, later than Cystoids and Crinoids; they had their golden age in the Carboniferous and Devonian times, but then disappeared. Their body was ovate, with five ambulacral areas, with each groove of which jointed pinnules were associated.

Class CYSTOIDEA. Wholly extinct.

The Cystoids are first found in Lower Silurian rocks, had their golden age in Upper Silurian times, and died out in the Carboniferous ages. Their body was ovate or globular, sessile or shortly stalked, covered with polygonal plates often irregularly arranged. They seem usually to have borne two to five feeble, unbranched arms.

Both Cystoids and Blastoids seem to have been half smothered in lime, and perhaps this is in part the explanation of their extinction. We cannot describe their structure here, but it is important to recognise that the Cystoids seem to occupy a central position in the group.

Development of the Echinodermata.

As the embryology of Echinodermata presents many difficulties, it will be convenient to begin with the most general results.

The ovum undergoes total segmentation, and a hollow ball of cells results. Apart from two alleged cases of delamination, a gastrula is always formed by the invagination of this blastosphere. Ectoderm and endoderm, or epiblast and hypoblast, are thus established.

The mesoblast has a two-fold origin: (*a*) from "mesenchyme" cells, which are separated from the invaginated hypoblast, and migrate into the segmentation cavity; (*b*) by the outgrowing of one or more cœlome pouches from the gastrula-cavity or archenteron. It is thus that the body-cavity and the rudiments of the water-vascular system arise.

The larva is, first of all, a slightly-modified, diffusely-ciliated gastrula. It becomes more modified, but preserves a bilateral symmetry. In Holothuroids, Echinoids, Asteroids, and Ophiuroids, the larva becomes quaintly modified by the outgrowth of external processes, and the formation of special ciliated bands. The larva of Crinoids (*i.e.*, of *Antedon* only) is not so divergent.

The larva does not grow directly into the adult. On the contrary the adult arises, for the most part, from new growth within the larva. The structures peculiar to the larva are absorbed, or in part thrown off. The formation of the calcareous foundation of the future adult is of the greatest morphological importance and interest. Only in a very few cases is the development direct.

Following the excellent account of Echinoderm embryology, contained in the *Vergleichende Entwicklungsgeschichte der wirbellosen Thieren* (Jena, 1890), by Korschelt and Heider, we shall distinguish four stages in development :—

1. The formation of the primary germinal layers, of the mesenchyme, and of the mouth and anus ;
2. The origin of the enterocœle (body-cavity) and of the hydrocœl (water-vascular system) ;
3. The differentiation of the typical larval forms ;
4. The modification of the larva into the adult Echinoderm.

1. *The formation of the primary germinal layers, of the mesenchyme, and of the mouth and anus.*

There is no difficulty in understanding how ectoderm and endoderm are established by the invagination of a blastosphere or blastula. The result is a ciliated gastrula. From the invaginating endoderm, somewhat amœboid cells are liberated into the persisting segmentation cavity. These will afterwards form part of the middle stratum, and it is likely that some of them remain unspecialised to form the rudiments of the future reproductive organs. The gastrula cavity or archenteron is the larval mid-gut ; the blastopore, or mouth of the gastrula, seems usually to become the anus ; but an invagination taking place at the other end forms a short fore-gut or stomatodæum.

2. *The formation of the enterocœl (body-cavity) and the hydrocœl (water-vascular system).*

There is a close connection between the origin of the body-cavity and that of the water-vascular system. Both are the results of an outgrowth or of outgrowths from the gastrula cavity or archenteron, into the sur-

rounding space between endoderm and ectoderm. As they have a common origin, the outgrowth or outgrowths which give rise to enterocœl and hydrocœl may be, and often are, termed vaso-peritoneal.

There is not perfect agreement as to this united origin, but the following facts are generally recognised.

In Holothuroids there is a single outgrowth which gives rise to both body-cavity and water-vascular system.

In Echinoids, Asteroids, and Ophiuroids, there are two outgrowths, from the left of which the water-vascular system arises.

In Crinoids (*Antedon*), there are three outgrowths, that which gives rise to the water-vascular system being independent of the pair which form the body-cavity.

In most cases a dorsal pore bringing the hydrocœl into communication with the exterior has been detected.

3. *The differentiation of the typical larval forms.*

The celebrated comparative anatomist and physiologist, Johannes Müller, was the first to show that the various types of Echinoderm larvæ might be derived from one fundamental form.

"This fundamental type is an elongated, oval or pear-shaped larva, which is somewhat flattened on its ventral side. It has arisen from a gastrula, whose blastopore has become the anus, while the archenteron is bent towards the ventral surface, where it communicates by the larval mouth with the exterior. Besides these two apertures, the larva has a third, namely, the dorsal pore of the water-vascular system. The cilia, with which the larva was at first uniformly covered, partly disappear, and persist only in restricted regions or ciliated bands." (Korschelt and Heider.)

Crinoids. The simplest Echinoderm larva is that of *Antedon*, a somewhat modified oval, with five transverse rings of cilia (the most anterior is less distinct), and an anterior terminal tuft.

Holothuroids. The larva of Holothuroids (an *Auricularia*) is much quainter. Its diffuse cilia are succeeded by a wavy longitudinal band, which in the *Pupa* stage breaks into transverse rings, usually five in number. The pre-oral region becomes large.

Asteroids. Nearest the *Auricularia* is the larva of starfishes, which has the same enlarged pre-oral region. There are *two* ciliated bands, of which the ad-oral is smaller, the ad-anal much larger. They are extended peripherally by the development of soft arms, and such a larva is known as a *Bipinnaria.* But this may be succeeded by a *Brachiolaria* stage, in which three warty arms are formed at the anterior dorsal end, independently of the ciliated bands.

Ophiuroids and *Echinoids.* In the *Pluteus* larvæ characteristic of these classes, the pre-oral region remains small, while the post-anal region becomes large. There is one undulating ciliated band, the course of which is much modified by the growth of six long arms, with temporary calcareous supports. This quaint form is often compared to a six-legged painter's easel.

4. *The modification of the larva into the adult Echinoderm.*

This history is so intricate and so difficult to understand without models, that I prefer to restate the general fact that the development is indirect, that the adult is a new formation within the larva, retaining the water-vascular system and mid-gut, but absorbing or rejecting the provisional larval structures. It is striking that in spite of the final differences, the first steps in the upbuilding of the adult, and especially of its skeleton, are closely parallel in the five classes.

One of the most important changes is that from bilateral to radial symmetry, in connection with which it is very likely that the primitive ancestor was bilaterally symmetrical, and that the radiate symmetry was acquired by early sessile or sedentary Echinoderms, such as the Cystoids.

It is very difficult to compare the Echinoderm larvæ, even in their simplest form, with those other animals. The nearest type is perhaps the *Tornaria* of *Balanoglossus*, but it again is very unique. One naturally tries to compare the Echinoderm larva with the Trochosphere of Annelids, but the differences are very marked.

Pedigree and Relationships of Echinoderms.

I shall not attempt to draw any genealogical tree, for that is apt to give an unwarrantable appearance of precision to merely tentative genealogies. The advanced student should read the remarkable chapter on Echinoderms in Neumayr's *Stämme des Thierreichs.* I think that the following conclusions are sufficiently cautious :—

(1) The Echinodermata do not seem to give origin to any other type, in the way for instance that "reptiles" evolved into birds, but it is possible that an offshoot from near the base of the Echinoderm branch was not far removed from the *Balanoglossus* twig, and was thus connected to Vertebrates.

(2) It is likely for many reasons that the Echinoderms arose from some worm type, to which the Holothurians retain more outward resemblance than do the others.

(3) From anatomical, embryological, and palæontological reasons, it is certain that the Holothurians, Echinoids, Asteroids, and Ophiuroids have diverged in a direction different from that along which Crinoids have evolved. Moreover, the Crinoids present many affinities with Blastoids and Cystoids.

(4) The Cystoids form a central class, and the general relationships may be represented thus (with one alteration after Neumayr).—

Ophiuroidea—Asteroidea ╲   ╱ Crinoidea
Echinoidea ╱ Cystoidea ╲ Blastoidea
Holothuroidea   (central)

SOME CONTRASTS BETWEEN THE FIVE EXTANT CLASSES OF ECHINODERMS.

HOLOTHUROIDEA.	ECHINOIDEA.	ASTEROIDEA.	OPHIUROIDEA.	CRINOIDEA.
The body is elongated and worm-like, with a tough muscular skin, in which limy plates are embedded.	The body is globular, heart-shaped, or flattened. Limy plates form a rigid shell, and bear movable spines. Pedicellariæ are present.	The body is flattened, pentagonal or stellate. The arms have a deep ventral ambulacral groove. The skin bears many limy plates, tubercles, etc., and pedicellariæ are present.	The body is a flat pentagonal disc, from which five plated arms, without any ambulacral groove, radiate abruptly.	A permanent or temporary jointed stalk bears a complex cup from which branched arms with lateral pinnules spread outwards.
They move partly by muscular writhings, partly by means of the tube-feet.	They move by means of the tube-feet, aided a little by the spines.	They move by means of the tube-feet.	They move by wriggling the muscular arms.	*Antedon* and other free comatulids swim gently, the others sway their arms on the top of stalks.
There is a circumoral nerve-ring, with radial branches. Sometimes there are "ear-sacs."	There is a circumoral nerve ring, with radial branches. There are "eyes."	There is the usual ambulacral nervous system, and there are eyes at the tips of the arms.	There is the usual ambulacral nervous system; there are no special sense-organs.	There is a motor and sensory antambulacral nervous system, and the usual ambulacral system, here exclusively motor. No special sense-organs.
The mouth surrounded by tentacles is at or near one pole, the anus at or near the other.	The mouth is in the middle of the ventral surface, the anus is usually at or near the opposite pole.	The mouth is ventral and central, the anus dorsal. Extensions of the digestive tract lie in the arms.	The mouth is ventral and central; there is no anus.	Mouth and anus are near one another on the upturned surface.
The circumoral water-ring communicates with the tentacles; the madreporic plate usually opens into the body-cavity; the tube-feet are often restricted and often mere papillæ without terminal discs.	The madreporic opening is on one of the five genital plates in the apical disc. The tube-feet end in discs.	The madreporic plate is dorsal and interradial. The tube-feet end in discs.	The madreporic plate is ventral, usually on one of the oral plates. The tube-feet are pointed, lateral, and small.	The water-vascular system communicates by several canals with the body-cavity, into which water enters from the exterior by numerous pores. The tube-feet are respiratory tentacles.
The reproductive organs are branched tubes in the body-cavity; they open near the base of the wreath of tentacles.	The reproductive organs lie under the apical region, and open on apical plates.	The reproductive organs lie in the arms, and open dorsally and interradially.	The reproductive organs lie in the body, and open interradially at the bases of the arms.	The functional parts of the reproductive organs are restricted to the pinnules, and open there.
Larva—an *Auricularia*.	Larva—a *Pluteus*.	Larva—a *Bipinnaria* or a *Brachiolaria*.	Larva—a *Pluteus*.	The larva of *Antedon* is barrel-shaped, with five transverse ciliated rings and a posterior tuft.

CHAPTER XIII.

ARTHROPODA.

ARTHROPODA: Animals with jointed appendages, including the following five classes :—

Crustacea (1).	Arachnoidea (5).	Insecta (4).	Myriopoda (3).	Protracheata (2).
Crabs. Lobsters. Water-fleas.	Spiders. Mites. Scorpions.		Centipedes and Millipedes.	*Peripatus.*
Mostly aquatic, breathing by gills.	Mostly terrestrial or aerial. Mostly breathing by air-tubes or tracheæ, hence called Tracheata.			

[*Note.*—There can be no doubt that the Crustacea and the Tracheata form two divergent series, but within the large and heterogeneous class of Arachnoidea are included the king-crab (*Limulus*), the "sea-spiders" (Pycnogonida), the extinct Eurypterids and Trilobites, all of aquatic habit.]

General Characteristics of Arthropods (to which primitive, parasitic, and degenerate forms present exceptions).

The body is bilaterally symmetrical, and consists of numerous segments variously grouped. Several or all of the segments bear paired jointed appendages variously modified. The cuticle is chitinous. The dorsal brain is connected by a ring round the gut with a double chain of ventral ganglia. Above the food-canal lies the heart. The true and primitive cœlome is always small in the adult; the apparent body-cavity is of secondary origin, and has in a great part a blood-carrying or vascular function. The sexes

are almost always separate, the reproductive organs and ducts are paired. There is often some metamorphosis in the course of development. In habit the Arthropods are predominantly active.

Class Crustacea.

General Characteristics of Crustaceans (to which primitive, parasitic, and degenerate forms offer exceptions).

With the exception of the land-crabs, wood-lice, and sand-hoppers, the Crustaceans live in water and breathe by gills, or through the skin. The head carries two pairs of antennæ along with other appendages; the thorax or median part of the body also bears limbs; the posterior region or abdomen is usually segmented, and often furnished with appendages. The typical appendage consists of two forks and a basal portion to which gills are often attached. To the chitin of the cuticle, carbonate of lime is added.

There are two sub-classes of Crustaceans :—

(1) Entomostraca, lower forms.	(2) Malacostraca, higher forms.
They are usually small and simple.	They are usually larger and more complex.
The number of segments and appendages is very variable.	The head consists of 5, the thorax of 8, the abdomen of 6 (or 7) segments.
The larva is hatched as a Nauplius.	The larva is usually higher than a Nauplius.
There is no gastric mill.	There is a gastric mill.
1. Phyllopoda, *Apus*, *Branchipus*, and *Artemia* (brine-shrimps) *Daphnia*, *Moina*, *Polyphemus*.	Leptostraca, *e.g.*, *Nebalia*.
2. Ostracoda, *Cypris*, *Cypridina*.	Arthrostraca, Amphipods (sand-hoppers, etc.). Isopods (wood-lice, etc.).
3. Copepoda, *Cyclops*, *Argulus*, many parasites.	Thoracostraca, *Cuma*. *Squilla*. *Mysis*. Shrimp, lobster, crayfish, crab.
4. Cirripedia, acorn shells and barnacles, *e.g.*, *Balanus* and *Lepas*.	

More Detailed Notes on the Characteristics of Crustaceans.

Of a class that includes animals so diverse as crabs, lobsters, shrimps, "beach-fleas," "wood-lice," barnacles, acorn-shells, and "water-fleas," it is difficult to state general characteristics, other than those few facts of structure which we have already summarised.

When we contrast Crustaceans with Insects, we remember of course that aquatic life is as general among the former as it is exceptional in the latter, and that the modes of respiration by gills and air-tubes respectively, or the characteristic modes of locomotion by swimming and flying are very different.

Admitting the parasitism of many Crustaceans, and the sedentary life of barnacles and acorn-shells, we must still allow that great activity characterises the class. With this may be connected the brilliant colouring, the power of colour-change, and the phosphorescence of many forms.

Except some primitive and degenerate forms, all are segmented. The typical appendage consists of a basal piece with two jointed branches. The cuticle is always chitinous, and often very much calcified. Perhaps the abundance of chitin explains the absence of cilia in Crustaceans and other Arthropods. The rigidity of the cuticle partially explains the necessity of frequent moults. As the muscles contract very rapidly, they illustrate the striated condition with great clearness. In crabs and some others the ventral ganglia are concentrated. Sensory organs are very well developed; both "eyes" and "ears" may occur away from the head. Much of the alimentary canal, which is almost always simple, consists of fore-gut and hind-gut. These are anterior and posterior invaginations of skin which meet the mid-gut or archenteron—the original gastrula cavity. The frequent presence of a gastric mill is quite intelligible, for it occurs in the fore-gut. The body-cavity is never very large, being mainly filled up with muscles and organs. In the blood hæmocyanin is the commonest respiratory pigment. In the body or skin lipochrome pigments, such as those which change from bluish green to red as the lobster is boiled, frequently

occur. Of modes of respiration, there are many grades,—by the general surface, by currents of water in and out of the posterior part of the food-canal, by thin plates on the legs, by well-formed gills. We miss the numerous excretory nephridia of Annelids; the green-glands of lobsters, etc., probably represent a pair; the shell-glands of Phyllopods and Copepods and some other structures seem to be in part at least excretory. It is possible that shell-making is an organised method of getting rid of some waste-products. There are many peculiarities connected with reproduction: thus parthenogenesis for prolonged periods is common among "water-fleas"; hermaphroditism occurs in barnacles, acorn-shells, etc.; the hermaphrodites are sometimes accompanied by pigmy "complemental" males; the two sexes are often very diverse, and the females of lower forms often carry the males about with them. The spermatozoa are usually exceptional in being very slightly motile. Some appendages are often modified for copulation or for carrying the eggs. The ova contain a considerable quantity of yolk, and the segmentation is always peripheral or centrolecithal, that is to say the core of yolk does not divide into cells, as the peripheral formative protoplasm does.

Life-History.—In the development of Crustaceans, there is almost invariably some metamorphosis, and often a very marked one. In other words, the larva hatched from the egg is rarely like the parent, and only acquires the adult characters after a series of profound changes. In some cases (*Nebalia*, *Mysis*) a metamorphosis takes place within the egg-cases, and in the few forms in which development seems to be direct slight traces of metamorphosis are found.

Almost all Entomostraca (lower Crustaceans) and the higher Crustaceans *Euphausia* and *Penæus* are hatched in a *Nauplius* stage,—with an unsegmented body, with three pairs of appendages of which the two posterior pairs are biramose, and with a median eye. The three pairs of appendages become the first and second pairs of antennæ and the mandibles of the adult. The head-region of the Nauplius becomes the head-region of the adult, the posterior region also persists, the new growth of segments and appendages

takes place (with numerous moultings) in the region between these.

The second important form of larva is the *Zoœa*, which has all the appendages on to the last maxillipedes inclusive, an unsegmented abdomen, and two lateral eyes in addition to the unpaired one of the Nauplius stage. As such most Decapoda are hatched.

(*a*) The crayfish (*Astacus*) is hatched almost as a miniature adult. The development is therefore very direct in this case.

(*b*) The lobster (*Homarus*) is hatched in a *Mysis* stage, in which the thoracic limbs are two-branched and used for swimming. After some moults it acquires adult characters.

(*c*) Crabs are hatched in the *Zoœa* form, and pass with moults through a *Megalopa* stage, in which they resemble certain Hermit-Crabs. The abdomen is subsequently tucked in under the carapace.

(*d*) *Penœus* (a kind of shrimp) is hatched as a *Nauplius*, becomes a *Zoœa*, then a *Mysis*, then an adult. Its relative *Lucifer* starts as a *Meta-Nauplius* with rudiments of three more appendages than the Nauplius. Another related form, *Sergestes*, is hatched as a *Protozoœa*, with a cephalothoracic shield and an unsegmented abdomen. Thus there are two grades between Nauplius and Zoæa.

Three facts must be borne in mind in thinking over the life-histories of crayfish, lobster, crab, and *Penœus* :—(1) there is a general tendency to abbreviate development, and this is of more importance when metamorphosis is expensive and full of risks; (2) there is no doubt that larvæ exhibit characters which are related to their own life rather than to that of the adult; (3) it is a general truth, that in its individual development the organism has to recapitulate to some extent the evolution of the race, that ontogeny recapitulates phylogeny. But while there can be no doubt that the metamorphoses of these Crustaceans is to some extent interpretable as a recapitulation of the racial history, for there were unsegmented animals before segmented forms arose, and the *Zoœa* stage is antecedent to the *Mysis*, etc., yet it does not follow that Crustaceans were once all like *Nauplii.* Moreover, this idea

of recapitulation offers a philosophical rather than a material explanation of the facts.

Habits and Habitats.—Most Crustaceans are carnivorous and predacious; others feed on dead creatures and organic débris in the water; a minority depend upon plants.

Parasitism occurs in over 700 species, in various degrees, and of course with varied results. Most of the parasites keep to the outside of the host (*e.g.*, Fish-lice), and suck nourishment by their mouths or by absorptive roots (Rhizocephala, *e.g.*, *Sacculina*). Sometimes the parasitism is temporary (*Argulus*); sometimes only the females are parasitic (*e.g.*, in *Lernæa*). The parasites tend to lose appendages, segmentation, sense-organs, etc., but the reproductive organs become more prolific. The hosts, *e.g.*, crabs infested by Rhizocephala, are sometimes materially affected, and even rendered incapable of reproducing.

Some Crustaceans live not as parasites but as commensals with other animals, doing them no harm, though sharing their food. Thus there is a constant partnership between some hermit-crabs and sea-anemones. The hermit-crab is concealed and protected by the sea-anemone; the latter is carried about by the Crustacean and gets fragments of food.

Masking is also common, especially among crabs. Some will cut the tunic of a sea-squirt and throw it over their own shoulders. Many attain a mask more passively, for they are covered with hydroids and sponges, which settle on the shell. There is no doubt, however, as to the frequent deliberateness of masking, for besides those known to use the Tunicate cloak, others have been seen planting seaweeds on their backs. The protective advantage of masking both in offence and defence is very obvious.

The intelligence of crabs and some of the higher Crustaceans is well developed. Maternal care is frequent. Fighting is very common, but the loss of limbs is readily repaired.

Deep-sea Crustaceans are very abundant, and often remarkable "for their colossal size, their bizarre forms, and brilliant red colourings;" some are blind, others are brilliantly phosphorescent. Yet more abundant are the pelagic Crustaceans (especially Entomostraca and Schizopods); they are often transparent except the eyes, often brightly coloured or phosphorescent. Many Crustaceans live on the shore, and con-

tribute greatly to the struggle for existence in that densely crowded region. The lower Crustaceans are abundantly represented in fresh-water, in pools, streams, and lakes. No small proportion of the lacustrine fauna, which is often very uniform over wide areas, consists of Crustaceans, which occur both at the surface and at the bottom. Then there are a few terrestrial Crustaceans, such as wood-lice, land-crabs. A few forms, usually blind, are found in caves.

History.—Fossil Crustaceans are found in Cambrian strata, but the highest forms (Decapoda) were not firmly established till the Tertiary period. Some of the genera, *e.g.*, the Branchiopod *Estheria*, living from Devonian ages till now, are remarkably persistent and successful. How the class arose, we do not know: it is probable that types like *Nebalia* give us trustworthy hints as to the ancestors of the higher Crustaceans; it is likely that the Phyllopods, *e.g.*, *Apus*, bear a similar relation to the whole series; the Copepods also retain some primitive characteristics; but it is difficult apart from mere guessing to say anything definite as to the more remote ancestry. The frequent occurrence of a Nauplius larva might lead one at first thought to suppose that the ancestral Crustacean must have been like a Nauplius. It is likely, however, that the Nauplius is a larval reversion to a much simpler form than that of the ancestral Crustacean, much in the same way as the Trochosphere larva of Molluscs is doubtless very much more primitive than the first Mollusc. We naturally think of a segmented worm-type as a plausible starting-point for Crustaceans, and it is not difficult to understand how a development of cuticular chitin would tend to produce a flexibly jointed limb out of an unjointed parapodium, how the mouth might be shunted a little backwards, and two appendages and ganglia a little forwards, and how division of labour would result in the differentiation of distinct regions.

Economic Importance.—Many of the Decapods are very good to eat; many smaller Crustaceans feed the fishes. A large number which devour débris are useful cleansers. Some are the hosts of important parasites, *e.g.*, that *Cyclops*, in which the guinea worm (*Dracunculus* or *Filaria medinensis*) passes part of its life.

Type. The Fresh-water Crayfish (*Astacus fluviabilis*).

(Most of the description will apply to the Lobsters (*Homarus* and *Palinurus*), and to the Norway Lobster (*Nephrops norvegicus*), often called a crayfish.

Mode of Life.—The fresh-water crayfish lives in streams, and burrows in the banks. It is not found in Scotland, but occurs here and there in England and Ireland, and is common on the Continent. It is absent from districts with little lime in the waters. Its food is very varied—from roots to water-rats, and cannibalism occurs. The animals swim actively backwards by powerful tail-strokes, or creep forwards on their "walking-legs." Their life is tolerably secure, but the frequent moultings are expensive and hazardous. The hatched young are like miniature adults, and cling for a while beneath the tail of the mother.

External Appearance.—The head and thorax are covered by a combined (cephalothoracic) shield; the abdomen consists of six separate rings and a terminal piece (telson) on which the food-canal ends. The stalked moveable eyes, the two pairs of feelers, the mouth with many appendages crowded around it, the gills under the side-flaps of the thoracic shield, the varied appendages with sensory, masticatory, combative, locomotor, and other functions, these and other features are obvious. But the plan of the animal must be realised; it consists of three groups of segments—five in the head, eight in the thorax, six in the abdomen, and the nineteen rings bear nineteen pairs of appendages, which by division of labour and other causes have come to be very heterogeneous. Yet in development and plan of structure, they are all similar, and illustrate clearly what is meant by "serial homology."

The Body-Wall consists of—

(1) The external cuticle, including various strata of chitin, plus or minus pigment and lime-salts;
(2) The ectoderm, epidermis, or hypodermis, which makes and remakes the cuticle;
(3) An internal connective-tissue layer with pigment, blood-vessels, and nerves.

Between the rings and between the joints the cuticle is not calcareous and is therefore pliable. As a sacrificed

DIAGRAM XII.

CRUSTACEAN APPENDAGES.

In this diagram, the appendages of the crayfish are arranged in three groups:—(*a*) those of the head; (*b*) those of the thorax; (*c*) those of the abdomen. Most of the figures are taken from Huxley's book on the crayfish.

Throughout *ex.* refers to exopodite, *en.* to the endopodite.

(*a*) 1, Antennule; 2, antenna; 3, mandible, with palp (*p.*); 4, first maxilla; 5, second maxilla;

(*b*) 6, first maxillipede; 7, second maxillipede; 8, third maxillipede; 9, forceps; 10–13, walking-legs; on several the gills (*br.*), and the setæ of the basal joint or coxopodite (*cxd.*) are shown; on appendage 8, the joints—coxopodite (*cxp.*), basipodite (*bp.*), ischiopodite (*ip.*), meropodite (*mp.*), carpopodite (*cp.*), propodite (*pp.*), and dactylopodite (*dp.*), are shown.

(*c*) 14, A, copulatory appendage of male; 14, B, rudimentary first abdominal appendage of female; 15, second abdominal appendage of male; 16, 17, 18, small unmodified swimmerets; 19, large swimmeret or terminal paddle.

Crustacean Appendages.

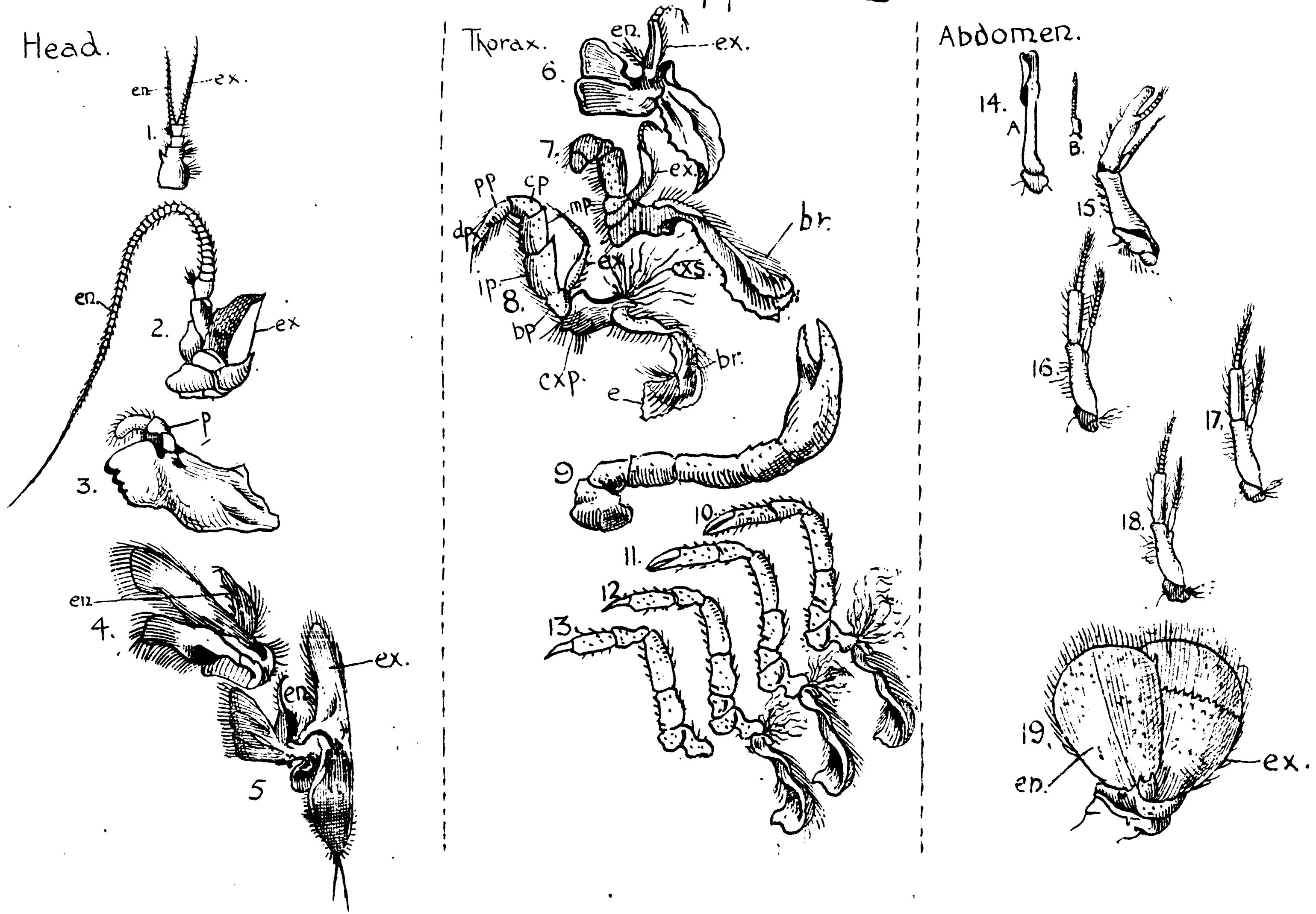


Diagram XII.

product of epidermic cells, it is dead and cannot expand. Hence the necessity for periodic moulting as long as the animal continues to grow. The old husk becomes thinner, a new one is formed beneath it, a split occurs across the back just behind the shield, the animal withdraws its cephalothorax and then its abdomen, and an empty but complete shell is left behind. The moulting is preceded by an accumulation of animal starch or glycogen in the tissues, and this is probably utilised in the growth which intervenes between the casting of the old and the hardening of the new shell. How thorough the cuticle-casting is, may be appreciated from the fact, that the covering of the eyes, the hairs of the ears, the lining of the fore-gut and hind-gut (both of them inturnings of skin), the gastric mill, and the tendinous inward prolongations of the cuticle to which some of the muscles are attached, are all got rid of and renewed. The moults occur in the warm months, eight times in the first year, five in the second, two in the third, after which the male moults twice, the female once a year, till the uncertain limit of growth is reached. It is not clearly known in what form the animals procure the carbonate of lime which is deposited in the chitinous cuticle, but experiments made by Mr Irvine at Granton Marine Station, proved that a carbonate of lime shell could be formed by crabs even when the slight quantity of carbonate of lime in sea-water was replaced by calcium chloride. Not the least remarkable fact in regard to moulting is the mortality which is often associated with the process itself or with the defenceless state which follows. Inequalities in the legs are usually due to losses sustained in combat, but these are gradually repaired by new growth.

The surface of the body bears hairs or bristles of various kinds. These have their roots in the epidermis, and are made anew at each moult. There are simple glands beneath the gill-flaps, and on the abdomen of the female there are cement-glands, the viscid secretion of which serves to attach the eggs.

Appendages.—The limbs of a Crustacean usually exhibit considerable diversity; in different regions of the body they are adapted for different work; yet they all have the same typical structure, and begin to develop in the same way. In other words, they are all homologous. Typically each con-

sists of a two-jointed basal piece (*protopodite*), and two jointed branches rising from this—an internal *endopodite* and an external *exopodite;* but in many, the outer branch disappears. We can fancy the origin of this form of limb from the similarly double "parapodium" of a Polychæte. The hard chitinous cuticle of the Arthropods makes joints possible and necessary. In regard to the following list of appendages, be it noted that the eye-stalks are no longer included in the series since their development is not that of the limbs, and, moreover, that though the two pairs of antennæ lie far in front of the mouth, it is likely that they have been shunted forward from a post-oral position. With many of the thoracic appendages, gills, plate-like epipodites, and setæ are associated.

An attempt should be made to connect the structure of the appendages with their functions. Thus it may be seen that the great paddles are fully spread when the crayfish drives itself backwards with a stroke of its tail, while in straightening again the paddles are drawn inwards, and the last joint of the exopodite bends in such a way that the friction is reduced. From the smallness of the exopodite in the third maxillipede, one may argue by analogy that in the succeeding thoracic appendages with only one fork the exopodite has disappeared. We may picture the gradual development of the claw by the irritation produced by the last joint biting against the second last. It is very likely that some of the crowded mouth parts, *e.g.*, the first maxillæ, are almost functionless. The hard toothed knob which forms the greater part of the mandible is obviously well adapted to its crushing work. With the great length of the endopodite in the antennæ, the reduced state of the exopodite may be connected.

In connection with the skeleton, the student should also notice the beak (*rostrum*) projecting between the eyes; the triangular area (*epistoma*) in front of the mouth, and the slight upper and lower lips; how the gills are protected by the flaps of the head-and-thorax shield; that each posterior segment consists of a dorsal arch (*tergum*), side flaps (*pleura*), a ventral bar (*sternum*), while the little piece between the *pleura* and the socket of the limb is dignified by the name of *epimeron;* and that the hindmost piece (*telson*) on which the food-canal ends ventrally is regarded by some as a

THE APPENDAGES OF THE CRAYFISH.

	No.	Name.	Function.	Structure.
Head (5).	1	Antennules (preoral?)	Tactile, olfactory, with ear-sac at base.	Typical.
	2	Antennæ (preoral?)	Tactile, opening of kidney at base.	Small exopodite.
	3	Mandibles.	Masticatory.	Four joints, of which three form the palp (endopodite).
	4	1st Maxillæ.	?	Thin 2-jointed protopodite, small endopodite, no exopodite.
	5	2nd Maxillæ.	Produces respiratory current.	Thin protopodite, filamentous endopodite, exopodite forms the baler (epipodite?)
Thorax (8).	6	1st Maxillipedes (foot-jaws).	?	Thin protopodite, small endopodite, large exopodite.
	7	2nd Maxillipedes	?	Two-jointed protopodite, five-jointed endopodite, long exopodite.
	8	3rd Maxillipedes	Masticatory.	Two-jointed protopodite, large five-jointed endopodite, slender exopodite.
	9	Forceps (clawed).	Fighting, seizing.	No exopodite. In the claw the last joint bites against a prolongation of the second last.
	10	Walking Legs (clawed).		
	11	,, ,,	Genital opening in female.	,,
	12	,,		Without claws.
	13	,,	Genital opening in male.	,,
Abdomen (6).	14	Modified swimmerets in male, in female rudimentary.	Serve in the male as canals for the seminal fluid.	Protopodite and endopodite form a canal; no exopodite.
	15	Modified swimmerets in male, normal in female.		All the three parts.
	16	Swimmerets.	Move slightly like oars, and carry the eggs in the female.	,,
	17	,,		,,
	18	,,		,,
	19	Great paddles.	Important in swimming.	,,

twentieth segment. The most difficult fact to understand clearly, is that the cuticle of certain mouth-parts (*e.g.*, the mandibles), and of the ventral region of the thorax, is folded inwards, forming chitinous "tendons," or insertions for muscles, protecting the ventral nerve cord and venous blood sinus, and above all, constituting the complex, apparently internal, "endophragmal" skeleton of the thorax.

Muscular System.—The muscles are white bundles of fibres. On minute examination these show clearly that transverse striping which is always well-marked in rapidly contracting elements. They are inserted on the inner surface of the cuticle, or on internal foldings (*apodemata*) of the same. The most important sets are, (1) the dorsal extensors or straighteners of the tail; (2) the twisted ventral flexors or benders of the tail, which have harder work, and are much larger than their opponents; (3) those moving the appendages, of which those attached to the mandibles are conspicuously seen in dissection; (4) the bands which work the gastric mill.

Nervous System.—The supra-œsophageal nerve-centres or ganglia, forming the brain, have been shunted far forward by the growth of the pre-oral region. We thus understand how the nerve-ring round the gullet, connecting the brain with the ventral chain of twelve paired ganglia, is so wide.

The dorsal or supra-œsophageal ganglia are three-lobed, and give off nerves to eyes, antennules, antennæ, and food-canal, besides the commissures to the sub-œsophageal centres.

The sub-œsophageal ganglia, the first and largest of the ventral dozen, innervate the six pairs of appendages about the mouth. There are other five ganglia in the thorax, and six more in the abdomen.

Though the ganglia of each pair are in contact, the ventral chain is double, and at one place, between the 3rd and 4th ganglia, an artery (sternal) passes through between the two commissures. From each pair of ganglia nerves are given off to appendages and muscles, and apart from the brain, these minor centres are able to control the individual movements of the limbs. In the thoracic region the cord is well protected by the cuticular archway already referred to.

From the brain, and from the commissure between it and the sub-œsophageal ganglia, nerves are given off to the

food-canal, forming a complex visceral or stomato-gastric system. Similarly from the last ganglia of the ventral chain, nerves go to the hind-gut. If the brain be regarded as the fusion of two pairs of ganglia, and so the development suggests, and the sub-œsophageal as composed of six fused pairs, then these, along with the eleven other pairs of the ventral chain, give a total of nineteen nerve-centres, or a pair for each pair of appendages

Sensory System.—A skin clothed with chitin cannot be very sensitive, but it seems that some of the bristles are. These are not mere outgrowths of the cuticle, but are continuous with the living epidermis beneath, and though some are only fringes, both experiments and histological observation show that some are *tactile.*

On the under surface of the outer fork of the antennules, there are special innervated bristles which have been credited with a *smelling* function.

Other still more innervated hairs have sunk into a sac at the base of the antennules, and are regarded as *auditory.* The sac opens by a bristle-guarded slit on the inner upper corner of the expanded basal joint, and contains a gelatinous fluid, and small "otoliths" which seem to be foreign particles. It is probable that this "ear" is somehow connected with directing the animal's movements. In some other Crustaceans, the auditory hairs are lodged in an open depression; this has become an open sac in the Crayfish, a closed bag in the Crab.

Small hairs on the upper lip of the mouth have been said to have a tasting function, but imagination is apt to help conclusions as to the precise nature of the sensitiveness of such simple structures.

The stalked eyes, which used to be regarded as appendages, arise in development from what are called "procephalic lobes" on the head. They are compound eyes, that is, they consist of a multitude of elements, each of which is structurally complete in itself. On the outside there is a cuticular cornea, divided into square facets, one for each of the optic elements. Then follows a focussing layer, corresponding to the epidermis, consisting of many crystalline cones. Each crystalline cone is composed of four crystalline cells, which taper internally. Internal to each crystalline

cone lies a retinula. The innermost part of this consists of four little red rods, united closely into what is called a rhabdome. Round about each rhabdome lie a number of black retinula cells, and at the base, a nerve fibre enters from the adjacent optic ganglion at the end of the optic nerve. Thus each element consists of corneal facet, crystalline cone, and retinula, and the retinula consists of internal rhabdome, and external retinula cells. Between the individual optic elements, lie some pigment cells. Opinions differ as to the visual powers of Crustaceans, but it seems likely that their eyes are able to form images of external objects.

Alimentary System.—The food-canal consists of three distinct parts, a fore-gut or stomatodæum developed by an intucking from the anterior end of the embryo, a hind-gut or proctodæum similarly invaginated from the posterior end, and a mid-gut or mesenteron which represents the original cavity of the gastrula.

The fore-gut, which is lined by a chitinous cuticle, includes a short gullet, on the walls of which there are small glands hypothetically called "salivary," and a capacious gizzard, or "stomach," which is distinctly divided into two regions. In the anterior (cardiac) region there is a complex mill, in the posterior (pyloric) region there is a sieve of numerous hairs. The mill is very complex, but there is no difficulty in dissecting it carefully, nor in seeing at once that there are supporting "ossicles" on the walls with external muscles attached to them, and internally projecting teeth which clash together and grind the food. Three of the teeth are conspicuous; a median dorsal tooth is brought into contact with two large laterals. On each side of the anterior part of the gizzard, there are two limy discs or gastroliths, which are broken up before moulting, and though of course inadequate to supply sufficient carbonate of lime for the new skeleton, seem to have some relation to this process. The occurrence of chitinous cuticle, hairs, teeth, and gastroliths in the "stomach," is intelligible when the origin of the fore-gut is remembered, and so is the dismantled state of this region when moulting occurs.

The mid-gut is very short, but it is the digestive and absorptive region. From it, there grows out on each side a large digestive gland with two ducts. This gland is much

more than a "liver," more even than a "hepatopancreas"; it is a "poly-enzymatic" gland, that is, one which produces diverse digestive ferments. It makes glycogen like the liver, and digestive juices comparable to those of the pancreas and the stomach of higher animals. The hind-gut is long and straight. It is lined by a chitinous cuticle, as its origin suggests. There are a few minute glands on its walls.

Body-Cavity.—The cœlome is for the most part filled up by the muscles and the organs, but there are interspaces left which contain some fluid with amœboid cells. Part of the cœlome also persists as the pericardium, or the chamber in which the heart lies.

Vascular System.—Within this non-muscular pericardium, and moored to it by thin muscular strands, lies the six-sided heart, which drives pure blood through the body, and receives pure blood again (*via* the pericardium) from the gills.

The arterial system is well-developed. Anteriorly, the heart gives off a median artery to the eyes and antennules, a pair of arteries to the antennæ, and a pair to the digestive gland. Posteriorly, there issues a single vessel, which at once divides into a superior abdominal, running along the dorsal surface, and a sternal which runs vertically through the body. The sternal passes through the connectives between the third and fourth ventral ganglia, and then divides into an anterior and posterior abdominal branch. All these arteries are continued into capillaries.

From the tissues the venous blood is gathered up in channels, which are not sufficiently defined to be called veins. It is collected in a ventral venous sinus, and passes into the gills. Thence purified and aerated by exposure on the water-washed surfaces, it returns by six vessels to the pericardium. From this it enters the heart by six large and several smaller apertures, which admit of entrance but not of exit.

The blood contains amœboid cells, and the fluid or plasma includes a respiratory pigment, hæmocyanin (bluish when oxidised, colourless when deoxidised), and a lipochrome pigment, called tetronerythrin. Both of these are common in other Crustaceans.

Respiratory System.—Twenty gills—vascular outgrowths of the skin—lie on each side of the thorax, sheltered by

the flaps of the shield. A current of water from behind forwards is kept up by the activity of the baling portion of the second maxilla. Venous blood enters the gills from the ventral sinus, and purified blood leaves them by the six channels leading to the pericardium.

Observed superficially, the gills look somewhat like feathers with plump barbs, but their structure is much more complex. The most important fact is that they present a large surface to the purifying water, while both the stem and the filaments which spring from it contain an outer canal continuous with the venous sinus, and an inner canal communicating with the channels which lead back to the pericardium and heart.

Three sets of gills are distinguishable. To the basal joints of the six appendages from the second maxillipede to the fourth large limb inclusive, the *podobranchs* are attached. They come off with the appendages when these are pulled carefully away, and each of them bears in addition to the feathery portion a simple lamina or *epipodite*. The membranes between the basal joints of the appendages and the body, from the second maxillipede to the fourth large limb inclusive, bear a second set, the *arthrobranchs*, which have no epipodites. In connection with the second maxillipede there is a single arthrobranch, in connection with each of the five following appendages there are two, so that there are eleven arthrobranchs altogether. There remain three *pleurobranchs*, one on the epimeron of the fifth large limb, and two others quite rudimentary on the two preceding segments. The basis of the podobranchs bears long setæ.

Excretory System.—A kidney or "green gland" lies behind the base of each antenna, and its opening is marked by a conspicuous knob on the basal joint of that appendage. Each kidney consists of a dorsal sac communicating with the exterior, and of a ventral coiled tube which forms the proper renal organ. The latter is supplied with blood from the antennary and abdominal arteries, and forms as waste-products uric acid and greenish guanin. Each kidney may be regarded as homologous with a nephridium.

Reproductive Organs.—The male crayfish is distingished from the female by his slightly slimmer build, and by the

copulatory modification of the first abdominal appendages. In both sexes the reproductive organs are three-lobed, and communicate with the exterior by paired ducts.

The testes consist of two anterior lobes lying beneath and in front of the heart, and of a median lobe extending backwards. Each lobe consists of many tubules within which the spermatozoa develop. From the junction of each of the anterior lobes with the median lobe, a genital duct or vas deferens is given off. This has a long coiled course, and ends in a short muscular portion opening on the last thoracic limb. The spermatozoa are at first disc-like cells, but they give off on all sides long pointed processes like those of a Heliozoon. The seminal fluid is milky in appearance, and becomes thicker in its passage through the genital ducts.

The ovaries are like the testes, but more compact. The eggs are liberated into the cavity of the organ, and pass out by short thick oviducts opening on the third last pair of walking legs. As they are laid they seem to be coated with the secretion of the cement glands of the abdomen, and the mother keeps her tail bent till the eggs are glued to the small swimmerets.

Before this, however, sexual union has occurred. The male seizes the female with his great claws, throws her on her back, and deposits the seminal fluid on the ventral surface of the abdomen. The fluid flows down the canal formed by the first abdominal appendages, and these seem to be kept clear by the movements of the next pair, which are also modified. On the abdomen of the female the agglutinated spermatozoa doubtless remain until the eggs are laid, when fertilisation in the strict sense is achieved.

Development.—The ovum has a central core of yolk, and is surrounded by a firm membrane. After fertilisation, peripheral segmentation begins, the central portion remaining for a while unchanged. A blastoderm or area of segmented cells extends all over the yolk.

The parts of the embryo begin to be mapped out on one portion of the ball of cells, known as the "ventral plate," although in reality it lies uppermost. The anterior region of this ventral plate shows the outlines of the head-lobes, behind these are hints of the appendages.

On a special area known as the "endoderm-plate," a slight

invagination occurs, representing the gastrula, whose typical formation is prevented by the quantity of yolk present. By this invagination a definite inner (endoderm) layer is established, and this is very soon accompanied by the beginning of a middle (mesoderm) stratum.

The stage of development at which three distinct appendages are developed is interesting, because it corresponds to the Nauplius, at which most of the lower Crustaceans and even the shrimp *Penæus* begin their free life. At this stage, in *Astacus*, a cuticle is formed and moulted. Soon, however, the masticatory appendages, then the walking limbs, and finally the abdominal parts are formed.

Derivatives of the epiblast or ectoderm.—(1) This layer forms the epidermis, its cuticle, and the inward prolongations of this. (2) The nervous system begins as an ectodermic thickening. (3) The eye arises (*a*) from the optic ganglion, developed in connection with the brain, (*b*) from an eye-fold or invagination, as the result of which the retinulæ are formed, and (*c*) from the epidermis, which forms the crystalline cells. The ear is formed from an invaginated sac. (4) The gills are in great part ectodermic outgrowths. (5) The green-gland is another invagination. (6) The hind-gut and the fore-gut are invaginations from opposite ends, meeting the endodermic gastrula cavity.

Derivatives of the hypoblast or endoderm.—From the cells invaginated into the yolk, at first as an open, but soon as a closed sac, the mid-gut is developed. The future digestive function is early suggested by the way in which the endoderm cells devour the surrounding yolk elements. From the primitive mid-gut the digestive gland is budded out.

Derivatives of the Mesoderm—The heart, its blood-vessels, the blood, the muscles, are due to this layer.

When the young crayfish are hatched and freed from their surrounding husks, they still cling to these, and thereby to the swimmerets of the mother. In most respects they are miniature adults, but the cephalothorax is convex and relatively large, the rostrum is bent down between the eyes, the tips of the claws are incurved and serve for firm attachment, and there are other slight differences. The note-

worthy fact is that the development is completed within the egg-case, and that it is continuous without metamorphosis. In contrast to this shortening of the life-history, the young lobster is liberated at what is called the *Mysis* or prawn stage, the young Crab as a yet simpler *Zoœa*, the young *Penæus* as a *Nauplius* with only three pairs of appendages. The shortened life-history of the crayfish is interesting in relation to its fresh-water habitat, where the risks of being swept away by currents are obviously great; but it must also be remembered that the tendency to abbreviate development is a general one. It seems that there is some maternal care in the crayfish, for the young are said sometimes to return to the mother after a short exploration on their own account.

SYSTEMATIC SURVEY OF THE CLASS CRUSTACEA.

FIRST SUB-CLASS. ENTOMOSTRACA.

These are the more primitive Crustaceans, often small and simple, with a variable number of segments and appendages. Out of the egg a Nauplius is hatched. The adult usually retains an unpaired frontal eye, and has no gastric mill.

Order 1. Phyllopoda.
Order 2. Ostracoda.
Order 3. Copepoda.
Order 4. Cirripedia.

Order 1. Phyllopoda. In these at least four pairs of swimming feet bear respiratory plates. The body is generally well segmented, and is protected by a shield-like or bivalve shell. The mandibles are without palps, and the maxillæ are rudimentary.

(*a*) Branchiopoda. The body has numerous segments and (10–20 or more) appendages with respiratory plates. The shell is rarely wanting, usually shield-like or bivalved. The heart is a long dorsal vessel with numerous openings. The eggs are able to survive prolonged desiccation.

Branchipus, a beautifully coloured fresh-water form, with hardly any shell.

Artemia. Brine-shrimps. Periodically parthenogenetic. By gradually changing the salinity of the water, Schmankewitsch was able, in the course of several generations, to modify *A. salina* into *A. mühlenhausii*, and *vice versa*.

Limnadia, with bivalve shell. Periodically parthenogenetic. A mollusc-like bivalve shell is still more marked in *Estheria*.

Apus, a fresh-water form with a large dorsal shield. Periodically parthenogenetic.

Of these *Apus* is certainly the most interesting. It is over an inch in length, and therefore a giant among Entomostraca. It has an almost world-wide distribution. "It possesses peculiarities of organisation which mark it out as an archaic form, probably standing nearer to the extinct ancestors of the Crustacea than almost any other living member of the group." From E. Ray Lankester's description of *Apus* (Quart. Journ. Micr. Sci., xxi., 1881), I take the following list of the appendages :—

Preoral.	1. Antenna. 2. Second antenna. (Like many others, I have been unable to find this. It is sometimes absent, and apparently always in certain species).
Oral.	3. Mandible. 4. Maxilla. 5. Maxillipede.
Thoracic (Pre-genital).	6. First thoracic foot (leg-like). 7–16. Other ten thoracic feet (swimmers). The 16th in the female carries an egg-sac or brood-chamber. There are eleven thoracic rings on the body.
Abdominal (Post-genital).	17–68. Fifty-two abdominal feet, to which there correspond only 17 rings on the body.

The large dorsal shield is not attached to the segments behind the one bearing the maxillipedes. Many of the thin limbs doubtless function as gills. The genital apertures are on the 16th appendages. The anus is on the last segment of the body.

The ventral nerve-cords are widely apart; and the cephalic ganglion is remarkably isolated. Lankester called the cephalic or supra-œsophageal ganglion an "archi-cerebrum," to emphasise its preoral position and its distinctness from posterior ganglia. Subsequent research has shown, however, that in *Apus* as in other Crustaceans, the cephalic ganglion is a "syn-cerebrum," that is to say, combined with the post-oral ganglia which have been shunted forwards.

(*b*) Cladocera. Small laterally compressed Crustaceans, with few and somewhat indistinct segments. The shell is usually bivalved. The head often projects freely. The second pair of antennæ are large, two-branched, swimming appendages, and there are 4–6 pairs of other swimming organs. The heart is a little sac with one pair of openings. The females have a brood-chamber between the shell and the back. Wit in this many broods are hatched throughout the summer. Periodic parthenogenesis (of the "summer-ova") is very common. "Winter-eggs," which require fertilisation, are set adrift in a part of the shell modified to form a cradle or ephippium.

Daphnia, *Moina*, *Sida*, *Polyphemus*, *Leptodora*, and many other "water-fleas" are extraordinarily abundant in fresh water, and form a part of the food of fishes.

Order 2. Ostracoda. Small Crustaceans, with an indistinctly segmented body, rudimentary abdomen, and bivalve shell. There are only seven pairs of appendages.

Cypris (fresh-water), *Cypridina* (marine).

Order 3. Copepoda. Elongated Crustaceans, usually with distinct segments. There is no shell. There are four (or five ?) pairs of two-branched thoracic appendages, and a five-jointed abdomen. The females carry the eggs in external ovisacs. Many are ecto-parasitic especially on fishes ("fish-lice"), and are often very degenerate. The free living Copepods form an important part of the food-supply of fishes.

Cyclops, free and exceedingly prolific in fresh water. *Cetochilus* free and abundant in the sea.

Sapphirina, a broad flat marine form about quarter of an inch long, occasionally parasitic. The male surpasses all animals in the brilliancy of its "phosphorescent" colour.

Chondracanthus. Here and in many others, the parasitic females carry the pigmy males attached to their body.

Caligus, a very common genus of "fish-lice."

Lernæa, *Penella*, *etc.* The adult females are parasitic, and almost worm-like. The males and the young are free. That the males are often free and not degenerate, while their mates are parasitic and retrogressive, may be understood by considering (1) the greater vigour and activity associated with maleness, (2) the fact that parasitism affords safety and abundance of nutrition to the females during the reproductive period.

Argulus, a divergent form temporarily parasitic on carp, etc. It has a shield-like cephalothorax and a small cleft abdomen. A protrusible spine projects in front of the blood-sucking mouth. There are four pairs of two-branched swimming appendages. There are two large compound eyes. The testes lie on each side of the abdomen. The female has no ovisacs; the eggs are laid on foreign objects.

Order 4. Cirripedia. Barnacles and acorn-shells, and some allied degenerate parasites.

Marine Crustaceans, which in adult life are fixed head downwards. The body is indistinctly segmented, and is enveloped in a fold of skin, usually with calcareous plates. The anterior antennæ are involved in the attachment, the posterior pair are rudimentary. The oral appendages are small, and in part atrophied. In most there are six (or less frequently four) pairs of two-branched thoracic feet, which sweep food particles into the depressed mouth. There is no heart. The sexes are usually combined, but dimorphic unisexual forms also occur. The hermaphrodite individuals occasionally carry pigmy or "complemental" males.

Lepas, the ship-barnacle, is as an adult attached to floating logs and to ship-bottoms. The anterior end by which the animal fixes itself is

drawn out into a long flexible stalk, containing a cementing gland, the ovaries, etc., and involving in its formation the first pair of antennæ and the front lobe of the head. The mouth region bears a pair of small mandibles and two pairs of small maxillæ, the last pair united into a lower lip. The thorax has six pairs of two-branched appendages, and from the abdomen a long penis projects. Around the body there is a fold of skin, and from this arise five calcareous plates, an unpaired dorsal *carina*, two *scuta* right and left anteriorly, two *terga* posteriorly. The nervous system is fairly complete, but there are no eyes. There is a complete food-canal and a large digestive gland. Beside the latter lie the lobes of the testis, from which a vas deferens runs to the penis. The oviducts from the ovaries in the stalk are said to open at the base of the anterior thoracic limbs, and the eggs are found in flat cakes between the external fold of skin and the body.

The life-history is most interesting. Nauplius larvæ escape from the egg-cases, and after moulting several times become like little Cyprid water-fleas. The first pair of appendages become suctorial, and after a period of free-swimming, the young barnacle settles down on some floating object, mooring itself by means of the antennary suckers, and becoming firmly glued by the secretion of the cement glands. Then important changes occur, the valved shell is developed, and the adult form is gradually assumed. While the early naturalists, such as Gerard (1597), regarded the barnacle as somehow connected with the barnacle-goose, and zoologists, before J. Vaughan Thompson's researches (1829), were satisfied with calling Cirripedes divergent Molluscs, we now know clearly that they are somewhat degenerate Crustaceans. We do not know, however, by what constitutional vice, by what fatigue after the exertions of adolescence, they are forced to settle down to sedentary life.

The food consists of small animals, which are swept to the mouth by the waving of the curled legs. Growth is somewhat rapid, but the usual skin-casting is much restricted except in one genus. Neither the valves, nor the uniting membranes, nor the envelope of the stalk are moulted, though disintegrated portions may be removed in flakes and renewed by fresh formations. An allied barnacle, *Scalpellum ornatum*, has separate sexes, and another species of this genus, *Scalpellum vulgare*, has a male which is not like a Cirriped, a fact which may be interpreted as an illustration of the superior vigour of the sex.

Balanus, the acorn-shell, encrusts the rocks in great numbers between high and low water marks. It may be described, in Huxley's graphic words, as a crustacean fixed by its head, and kicking its food into its mouth with its legs. The body is surrounded, as in *Lepas*, by a fold of skin, which forms a rampart of six or more calcareous plates, and a fourfold lid consisting of two *scuta* and two *terga*. When covered by the tide the animal protrudes and retracts between the valves of the shell six pairs of curl-like double thoracic legs. The structure of the acorn-shell is in the main like that of the barnacle, but there is no stalk.

The life-history also is similar. A Nauplius is hatched. It has the usual three pairs of legs, an unpaired eye, and a delicate dorsal shield. It moults several times, grows larger, and acquires a firmer shield, a

longer spined tail, and stronger legs. Then it passes into a *Cypris*-stage, with two side eyes, six pairs of swimming legs, a bivalve shell, and other organs. As it exerts itself much but does not feed, it is not unnatural that it should sink down in over-fatigue. It fixes itself by its head and antennæ, and is glued by the secretion of the cement gland. Some of the structures, *e.g.*, the side eyes and the bivalve shell, are lost; new structures appear, *e.g.*, the characteristic Cirriped legs and the shell. Throughout this period, which Darwin called the "pupa-stage,' there is external quiescence, and the young creature continues to fast. The skin of the pupa moults off; the adult structures and habits are gradually assumed. At frequent periods of continued growth, the whole lining of the shell and the skin of the legs are shed. In spring these glassy cast coats are exceedingly common in the sea. Acorn-shells feed on small marine animals. They fix themselves not to rocks only, but also to shells, floating objects, and even to whales and other animals.

Alcippe and *Cryptophialus* (with only three or four pairs of feet) live in the shells of other Cirripedes or of Molluscs; *Proteolepas* is parasitic in the mantle of other Cirripedes, and like a grub.

The abdomen of a crab or of a hermit-crab often shelters some species of *Sacculina* or of *Peltogaster*, the most degenerate of all parasites. The creature is little more than a sac of reproductive organs, and yet it started in life as a Nauplius, and became a Cyprid larva like many another Crustacean. The body is a rounded sac, corresponding to the head region of the larva. There is no food-canal, nor trace of segmentation or appendages. The sac is fixed by absorptive "roots," which have insinuated themselves into the viscera of the crab. The sac-like body contains a brood-cavity and hermaphrodite reproductive organs, but sometimes there are associated pigmy males.

SECOND SUB-CLASS. MALACOSTRACA.

These are higher Crustaceans in which the body consists of three regions with a constant number of segments, five to the head, eight to the thorax, and six to the abdomen (except in forms like *Nebalia*, which have seven). The terminal piece or telson of the abdomen is regarded by some zoologists as a distinct segment. Apart from this telson, and also the segment next to it in *Nebalia*, all the segments bear paired appendages. More or less of the thorax is fused to the head region, and the anterior thoracic limbs are usually auxiliary to mastication. Two compound lateral eyes and a gastric mill are always present. The female genital apertures are on the third last pair of thoracic legs, the male apertures on the last pair. Very few are hatched in the Nauplius stage, many however at the Zoæa level, while others have no metamorphosis at all.

Legion 1. Leptostraca. *Nebalia.*
Legion 2. Arthrostraca, with three orders, Anisopoda, Isopoda, Amphipoda.
Legion 3. Thoracostraca, with four orders, Cumacea, Stomatopoda, Schizopoda, Decapoda.

Legion 1. Leptostraca.

Marine Crustaceans of great systematic interest, because they retain in many ways the simplicity of ancestral forms. The most important genus is *Nebalia*.

A bivalve shell covers the whole of the lank body, except the last four abdominal segments; the head is free from the thorax; the eight segments of the thorax are free from one another, and the plate-like appendages resemble those of Phyllopods; the abdomen has seven segments and a telson with two forks; the elongated heart extends into the abdomen and has seven pairs of lateral apertures or ostia. *Nebalia* and its congeners are probably related to certain ancient fossil forms from Palæozoic strata—*Hymenocaris*, *Ceratiocaris*, *etc.*

Legion 2. Arthrostraca. (Edriophthalmata, sessile-eyed).

There is no shell-fold or shield except in the order Anisopoda. The first thoracic segment (rarely with the addition of the second) is fused to the head, the corresponding appendages serve as maxillipedes, the other thoracic segments (seven or six) are free. The eyes are sessile.

Order 1. Anisopoda. The fusion of the first two thoracic segments to the head, the presence of a cephalothoracic shield, and other divergent features distinguish *Tanais*, *Apseudes*, etc., from the Isopoda.

Order 2. Isopoda. The body is flattened from above downwards. The first thoracic segment is fused to the head, while the other seven are free, and there is no cephalothoracic shield. The abdomen is usually short, and its appendages, usually overlapped by the first pair, are plate-like and function as respiratory organs.

The "wood-lice" (*Oniscus*, *Porcellio*) are familiar animals which lurk in damp places under stones and bark, and devour vegetable refuse. Some related forms (*e.g.*, *Armadillo*) which roll themselves up are called "pill-bugs." In the terrestrial forms there is obviously a departure from the ordinarily aquatic habit of Crustaceans, but we do not know that there is any special development of respiratory structures.

Asellus is a very common form, living in both fresh and salt water.

Idotea is not uncommon among the shore rocks

The "gribble" (*Limnoria lignorum*) is a destructive marine Isopod which eats into wood.

Among the marine Cymothoidæ which are often parasitic on fishes, some, *e.g.*, *Cymothoa*, are remarkable in their sexual condition, for they are hermaphrodites in which the male

organs mature and become functional when the oviducts are still closed, while at a later period in life the male organs are lost and the animals become functionally female.

The Bopyridæ infest the gill-chambers of other Crustaceans. The pigmy males are usually carried about by their mates.

Among the parasitic Cryptoniscidæ, we again find hermaphrodites with associated pigmy males.

Many of these Isopods, like not a few other Crustaceans, are extremely interesting to those who care to think about the problem of sex. Thus, to cite one other instance, the males and females in the genus *Gnathia* are so unlike, that they have been referred to different sub-families.

Order 3. Amphipoda. The body is laterally compressed. In most it is only the first thoracic segment which is fused to the head, in the "no-body-crabs" (*Caprellidæ*), and "whale-lice" (*Cyamidæ*), two segments are involved. The thoracic limbs bear respiratory appendages. Of the six pairs of legs which the abdomen usually bears, the anterior three are usually more strongly developed as swimmers, while the posterior three are used in jumping.

Gammarus pulex is very common in fresh water.

Other species occur on the sea-shore. There also the "Beach-fleas" (*Talitrus* and *Orchestia*) are exceedingly abundant. On solid ground they move on their sides in a strange fashion, but they swim very swiftly.

Hyperia, *Phronima*, and many marine Amphipods, have a habit of living as commensals with other animals.

Caprella, a common marine gymnast on sea-weeds, has the trunk of the body reduced to the quaintest possible minimum.

Cyamus is parasitic on the skin of whales.

Legion 3. Thoracostraca. (Podophthalmata, with stalked eyes).

Several or all of the thoracic segments are fused to the head, and there is a cephalothoracic shield overlapping the gills. The two eyes are stalked except in Cumacea.

Order 1. Cumacea. The cephalothoracic shield is small, and four to five thoracic segments are left uncovered and free. The eyes are sessile and adjacent or fused. There are two pairs of maxillipedes. The females have no abdominal appendages except on the last segment. The genera are marine, *e.g.*, *Cuma* or *Diastylis*.

Order 2. Stomatopoda. The shield is still small and does not cover the three posterior thoracic segments. The body is somewhat flattened, the abdomen is very strong. Five anterior thoracic appendages are directed towards the mouth and serve to catch food, and to clamber. The five anterior abdominal legs carry feathery gills, the sixth pair form swimming paddles. The elongated heart extends into the abdomen, which also contains the reproductive organs. The genera are marine, *e.g.*, *Squilla*.

Order 3. Schizopoda. A delicate shield covers the whole of the thorax, but there is still some freedom as to one or more of the posterior thoracic segments. The eight thoracic appendages are very uniform, but the first two may serve as maxillipedes. The

abdominal appendages of the male are strongly developed, those of the female are weak except the last, which in both sexes form paddles. They are marine forms, *e.g.*,—*Mysis* (without gills on the thoracic legs), *Lophogaster* and *Euphausia* (with gills on the thoracic legs). The last named starts in life as a Nauplius. As an adult it has numerous phosphorescent organs.

Order 4. Decapoda. The shield is large and firm, and is fixed to the dorsal surface of all the thoracic segments. Of the thoracic appendages, the first three pairs are maxillipedes, the five other pairs are walking-legs (whence the term Decapod).

Sub-order 1. Macrura. Abdomen long. *Homarus* (lobster); *Nephrops* (Norway-lobster, sea-crayfish); *Astacus*, (fresh-water crayfish; *Palinurus* (rock-lobster), whose larva was long known as the glass-crab (*Phyllosoma*); *Penæus* a shrimp which passes through Nauplius, Zoæa, and Mysis stages; *Lucifer* and *Sergestes* are also hatched at a stage antecedent to the Zoæa; *Crangon vulgaris* (the British shrimp); *Palæmon, Pandalus*, *Hippolyte* (prawns); *Galathea* (with the abdomen bent inwards); *Pagurus*, *Eupagurus* (hermit-crabs); *Birgus latro* (the terrestrial robber or palm-crab). Opinion seems to incline against recognising a separate sub-order (Anomura) for the soft-tailed hermit-crabs.

Sub-order 2. Brachyura. Abdomen short, and bent under the cephalothorax. *Cancer* (edible crab); *Carcinus mænas* (green shore-crab); *Portunus* (swimming-crab); *Maia* (spider-crab); *Lithodes* (stone-crab); *Porcellana*; *Dromia* (often covered by a sponge); *Pinnotheres* (living inside bivalves); *Gelasimus* (fiddler-crab, a very adept burrower); *Telphusa* (a fresh-water crab); *Gecarcinus* (land-crabs, only visiting the sea at the breeding season).

Second Set of Arthropoda—TRACHEATA, including four Classes:—

1. PROTRACHEATA.	2. MYRIOPODA.	3. INSECTA.	4. ARACHNOIDEA.
Peripatus alone.	Centipedes and Millipedes.	or Hexapoda.	Scorpions, Spiders, Mites, King-crab, etc.
with pre-oral antennæ (Antennata).			A heterogeneous class, but with no preoral antennæ (Chelicerota).

General Characters of Tracheata.

Most of the Tracheata live on land or in the air, but there are exceptions, *e.g.*, those larval insects which live in fresh water, and the king-crab which is marine.

The typical respiratory structures are air-tubes or tracheæ,

but scorpions have "lung-books," and most spiders have both lung-books and tracheæ, while the king-crab has "gill-books."

Except the mouth-parts of Insects, the appendages are not forked like those of Crustaceans.

First Class of Tracheata—PROTRACHEATA, including one genus, *Peripatus*.

General Characters of Protracheata.

The body is in form like that of a worm or caterpillar, soft-skinned, and without external segmentation.

There is a pair of prominent pre-oral antennæ.

The true appendages are—a pair of jaws in the mouth, a pair of slime-secreting oral papillæ, numerous pairs of short, imperfectly jointed legs with two claws apiece, and a pair of anal papillæ. The legs contain peculiar (coxal) glands.

Respiration is effected by numerous tracheæ, whose openings are somewhat scattered on the surface of the body. The heart is simply an elongated dorsal vessel with valvular openings. There is a series of excretory tubes or nephridia. The halves of the ventral nerve-cord are widely separate.

The single genus *Peripatus* is represented by numerous (twelve) species, widely distributed; in its possession of tracheæ and nephridia it is an interesting connecting link; in many ways it seems to be an old-fashioned survivor of an archaic type.

The species of *Peripatus* are beautiful animals. Sedgwick says—"The exquisite sensitiveness and continually changing form of the antennæ, the well-rounded plump body, the eyes set like small diamonds on the side of the head, the delicate feet, and, above all, the rich colouring and velvety texture of the skin, all combine to give these animals an aspect of quite exceptional beauty." As to their habits, Hatchett Jackson says—"They live under stones, in rotting wood, etc., in moist places, are nocturnal in habit, and feed on insects, etc., which they ensnare by the ejection of slime from the oral papillæ." To their shy habits, their persistence is possibly in part due. They are able to move quickly, somewhat after the fashion of Millipedes, especially like *Scolopendrella*. Young forms roll up when touched, and have been seen to climb up vertical glass plates.

The species acknowledged by Sedgwick are:—Four from South Africa—*P. capensis*, *P. balfouri*, and *P. brevis* from Table Mountain, and *P. moseleyi* from near Williamstown; two from Australasia—*P. novæ zealandiæ* from New Zealand and *P. leuckarti* from Queensland; seven from neotropical regions—*P. edwardsii* from Caracas, *P. imthurmi* or *demeraranus* from Demerara, *P. trinidadensis* and *P. torquatus* from Trinidad, *P. iuliformis* from St. Vincent, *P. chilensis* from Chili, *P. quitensis* from Ecuador, besides which there are some doubtful forms. I have quoted the species in order to illustrate how widely this remarkable genus is distributed.

As the different species have similar habits and live in very similar conditions, the differences between them perhaps illustrate purely constitutional variations.

A more Detailed Account of Peripatus.

Form.—The body suggests an Annelid or a caterpillar, but apart from the appendages there is no external segmentation. Over the soft skin are numerous minute warts with small bristles. The mouth is ventral anteriorly; the anus is terminal posteriorly.

Appendages.—The two large, ringed antennæ do not seem to be homologous with limbs. The first pair of appendages—double sickle-like jaws—lie in the mouth cavity. A little further back are two oral papillæ from which slime is exuded. Then there are the 14–42 stump-like legs, each with two terminal chitinous claws. In the young *P. capensis* the leg is said to be five-jointed, but in the adults there is no trace of this. In respect to its legs, therefore, *Peripatus* is hardly an Arthropod.

Skin.—The chitinous cuticle, ordinarily thick in Arthropods, is delicate. The ectoderm [hypodermis, or epidermis] is a single layer of cells.

The *Muscular System* is very well developed. (1) Externally there is a layer of circular muscles; (2) within this lies a double layer of diagonal fibres; (3) internally there are strong longitudinal bundles. Finally, in connection with this internal layer there are fibres which divide the body-cavity into a median and two lateral compartments. The median includes heart, gut, slime glands, reproductive organs; the laterals include the nerve-cords, the salivary glands; the legs contain nephridia and coxal or crural glands. Striped, rapidly contracting muscles are characteristic of Arthropods, but in *Peripatus* the muscles are unstriped, excepting those which work the jaws and are perhaps the most active.

The *Nervous System* consists of a dorsal brain, and two widely separate lateral-ventral nerve-cords. These are connected transversely by numerous commissures, are slightly swollen opposite each pair of legs to which they give off nerves, and are united posteriorly over the anus. They are not ganglionated, but are covered by a continuous layer of ganglionic cells. The brain is very homogeneous, simpler than that of most Insects. From the brain, nerves pass to the antennæ, etc., and two viscerals or sympathetics, soon uniting, innervate the anterior part of the gut. Sense-

organs are represented by two simple eyes on the top of the head. These are most like the eyes of some marine Annelids. Behind each there lies a special optic lobe connected with the brain, but the eye itself arises as a dimple in the skin.

Alimentary Canal.—Round about the mouth, papillæ seem to have fused to form a "mouth-cavity," which includes the mandibles, a median pad or tongue, and the opening of the mouth proper. The mouth leads into a muscular pharynx, into which opens the common duct of two large salivary glands, which extend far back along the body. Mouth, pharynx, and short œsophagus are lined by a chitinous cuticle, like that of the exterior. The long digestive region or mid-gut extends from the second leg nearly to the end of the body. Its walls are plaited. Finally, there is a short rectum, lined by a chitinous cuticle.

Circulatory System.—The dorsal blood-vessel forms a long contractile heart. It lies within a pericardial space, and receives blood by segmentally arranged apertures with valves. The circulation is mostly in ill-defined spaces in the body-cavity, which has therefore been called a "hæmocœle."

The *Respiratory System* consists of very long and very fine unbranched tracheæ, which are widely distributed in the body; a number open together to the exterior in flask-like depressions. These openings or stigmata are diffuse and irregular in *Peripatus edwardsii*, but in *P. capensis* there is a dorsal and ventral row on each side. In *P. novæ-zealandiæ* the tracheæ are said to be branched.

The *Excretory System.*—A pair of nephridia lie in each segment. Each consists of an internal terminal funnel, a looped canal, and a wide vesicle which opens near the base of each leg. They are not very different from those of many Annelids, but their occurrence in a Tracheate is remarkable. The salivary glands, the genital ducts, and two anal glands opening near the anus are regarded as modified nephridia. It may be noted, too, that the same is perhaps true of the "coxal glands" of *Limulus* and of the antennary glands of Crustaceans.

Crural or Coxal Glands lie in the legs and open to the exterior. Their meaning is uncertain, their occurrence is variable. Thus in *P. edwardsii* they occur in the males only, in *P. capensis* they are present in both sexes. The large mucus glands, which pour forth slime from the oral papillæ, are regarded as modified coxal glands.

Reproductive System.—(*a*) Female (of *P. edwardsii*).—From the two ovaries, which are surrounded by one connective tissue sheath, the eggs pass by two long ducts leading to a common terminal vagina opening between the second last legs. These ducts are for the most part uteri, but on what may be called the oviduct portions adjoining the ovaries, there are two pairs of pouches—(*a*) a pair of receptacula seminis (for storing the spermatozoa received during copulation), and a pair of receptacula ovorum for storing fertilised eggs. In *P. capensis* the ovary is halved rather than paired, and there are a few other differences between the species. In male and female alike, of this species at least, the ducts are not in direct connection with the reproductive organs.

The eggs are hatched in the uteri, and all stages are there to be found in regular order. The young embryos seem to be connected to the wall of the uterus by what has been called a "placenta," so suggestive

is it of mammalian gestation. The older embryos lose this "placenta," but each lies constricted off from its older neighbour in front and younger neighbour behind. When born the young resemble the parents except in size and colour. In *P. novæ zealandiæ*, the ova pass from the ovary into the uterus in December, and the young are born in July—a long period of gestation.

(*b*) Male (of *P. edwardsii*). The male elements are produced in small testes, pass thence into two seminal vesicles, and onwards by two vasa deferentia into a long single ejaculatory duct, which opens in front of the anus. In the ejaculatory duct the spermatozoa are made into a long packet or spermatophore, which is attached to the female during copulation.

[While it is characteristic of Arthropods, in which the development of chitin is so predominant, that ciliated epithelium is absent, it seems that in *Peripatus*, which is much less chitinous than the others, ciliated cells occur in some parts of the reproductive ducts, and perhaps also at the internal funnels of the nephridia. This is indeed what one would expect.]

Development of Peripatus.—There is a strange variety of development in different species of this genus. Thus there is much yolk in the ovum of *P. novæ zealandiæ*, extremely little in that of *P. capensis*. In the former species the yolk has a manifold origin; it is said to arise in the protoplasm of the ovum itself from the breaking up of the germinal vesicle, from surrounding follicle cells, and from yolk present within the ovary. In *P. capensis* and *P. balfouri* spermatozoa reach the ovary, and there probably the ova are fertilised, but in *P. novæ zealandiæ* the spermatozoa are confined to the receptaculum seminis near which fertilisation seems to occur. In the maturation of the ova of *P. capensis* and *P. balfouri* two polar bodies are extruded as usual, but none have been observed in the case of *P. novæ zealandiæ*.

In *P. capensis* the "segmentation" is remarkable, for true cleavage of cells does not occur. The fully "segmented" ovum does not exhibit the usual cell limits. It is a protoplasmic mass—or syncytium—with many nuclei. Even when the body is formed the continuity of cells persists, nor does the adult lack traces of it. To Professor Sedgwick, this singular fact suggested the theory that the Metazoa may have begun as multi-nucleated Infusorian-like animals.

The gut appears as a large vacuole within the multi-nucleated mass, and a gastrula stage is thus established.

In the ova of *P. novæ zealandiæ*, which have much yolk, a superficial multiplication of nuclei forms a sort of blastoderm which spreads over almost the entire ovum. The segmentation in this case has been called centrolecithal (the type characteristic of Arthropods), but it is again true that for a long time the cells do not exist as well-defined units. It has been said, indeed, that "the embryo is formed by a process of crystallising out *in situ* from a mass of yolk, among which is a protoplasmic reticulum containing nuclei."

From these examples the student will perceive how difficult it is to give a succinct account of the development of *Peripatus*.

Development of Organs.

The hypodermis is ectodermic, the cuticle an external product thereof.

The muscles are as usual derived from the mesoderm, which arises from two ventral mesodermic strands. These are subsequently divided into hollow segments. The true body-cavity or cœlome is represented by the original cavities of the mesoderm segments. In the adult this series of truly cœlomic cavities is hardly represented except by the innermost portions of the nephridia. The apparent body-cavity is a secondary cavity, consisting, for the most part, of blood-carrying or vascular spaces, subsequently established in the mesoderm. It is divided into five regions, the central space, the two lateral cavities, and the cavities of the legs.

The appendages are outgrowths of the body-wall. They, and all the segmentally arranged parts, develop progressively from in front backwards.

The nervous system is derived from ectodermic thickenings which sink inwards. It develops from in front of the mouth backwards.

The food-canal consists of the long endodermic mid-gut or mesenteron (the gastrula cavity), of an anterior ectodermic invagination forming pharynx and gullet (fore-gut or stomatodæum), and of a short posterior ectodermic invagination forming the rectum (hind-gut or proctodæum).

The nephridia have a two-fold origin. The internal funnel is derived directly from part of a mesodermic segment or vesicle. The rest of the nephridium is invaginated from the ectoderm.

The reproductive organs arise on the epithelium of a persistent portion of the true cœlome or primitive body-cavity.

Zoological Position of Peripatus. I shall summarise what Lang says on this subject in his work on Comparative Anatomy.

Annelid Characteristics, Tracheate Characteristics, of Peripatus.

Annelid Characteristics	Tracheate Characteristics
Segmentally arranged nephridia as in Chætopods.	The presence of tracheæ.
Segmentally arranged coxal glands, like similar glands in some Chætopods.	The nature of the heart and the lacunar circulation.
The muscular ensheathing of the body.	The modification of appendages as mouth-organs.
Less important are the stump-like legs and the simple eyes.	The form of the salivary glands.
	The smallness of the genuine body-cavity or cœlome.

The ladder-like character of the ventral nervous system (cf. primitive Molluscs, Phyllopod Crustaceans, and Nemerteans.) is probably primitive. That salivary glands and genital ducts are homologous with nephridia is a fact of much morphological importance. It is possible that the mucus glands are modifications of coxal or crural glands, and that the latter are homologous with the parapodial glands of some Annelids. It is not certain that the antennæ, jaws, and oral papillæ of *Peripatus* precisely correspond to the antennæ, mandibles, and first maxillæ of Insects.

Our general conclusion is that Peripatus is an archaic type, a survivor of forms which were ancestral to Tracheata and closely related to Annelids.

Second Class of Tracheata. MYRIOPODA. Centipedes and Millipedes.

These animals retain a worm-like shape; the numerous rings of the body and the appendages they bear are very uniform; there is little division of labour. It would be rash to assert that any of the modern Myriopods are stages in the pedigree of Insects, but the two classes are branches from one base, and it is likely that the simplest Insects were in some ways like Myriopods.

Both centipedes and millipedes live on land, but two or three of the latter (*e.g.*, a species of *Geophilus*) occur on the sea-shore. Most of them are very shy animals, lurking in dark places and avoiding the light. They breathe like other Tracheata.

The head bears a pair of antennæ, and two pairs of appendages—mandibles and maxillæ. The limbs are six or seven jointed, clawed, and very uniform. The nervous system, heart, excretory tubules, etc., are like those of Insects.

MYRIOPODA.

Centipedes. Chilopoda.	Millipedes. Diplopoda (or Chilognatha).
Carnivorous. Poisonous. Body usually flat.	Vegetarian. Harmless. Body cylindrical.
A pair of appendages to each segment.	By the imperfect separation of the segments all but the most anterior seem to have two pairs of appendages each, and also two paired ganglia, and two pairs of stigmata.
Many-jointed antennæ. Toothed cutting mandibles. Each maxilla consists of an external palp, and a bi-lobed median portion.	Seven-jointed antennæ. Broad masticating mandibles. Maxillæ are represented by a four-lobed plate.
The next appendage is leg-like. Then follows a large basilar plate, beside which are the two poison-claws.	No basilar plate.
A single posterior genital aperture.	Genital apertures open on the second or third pair of limbs.
Examples—*Scolopendra.*	Examples—*Julus.*

As distinct from these two sub-classes, it is perhaps necessary to recognise other two—Pauropoda, *e.g.*, *Pauropus*, and Symphyla, *e.g.*, *Scolopendrella.*

Third Class of Tracheata. Insecta.

It is said that there are about two million species of living animals, and that almost half of these are Insects.

Insects occupy a position among the backboneless animals like that of birds among the Vertebrates. The typical members of both classes have wings and the power of true flight, richly aërated bodies, and highly developed nervous and sensory organs. Both are very active and brightly coloured. They show parallel differences between the sexes, and great wealth of species within a narrow range.

Like other Arthropods, Insects have segmented bodies, jointed legs, chitinous armature, and a ventral chain of ganglia linked to a dorsal brain. But what are their characteristics? Compared with *Peripatus* and the Myriopods, adult Insects show concentration of the body-segments, decrease in the number and increase in the quality of the appendages, and wings withal. The young stages, however, are often more primitive.

Insects are terrestrial and aërial Arthropods, which are usually winged as adults, which breathe air by means of tracheæ, and often have a metamorphosis in the course of their growth. The adult body consists (1) of a head with three pairs of appendages (=legs) and a pair of pre-oral outgrowths—the antennæ or feelers, (2) of a thorax of three segments, each with legs, the last two with wings, and (3) of an abdomen with segments, but with no legs unless rudimentary modifications of these be represented by stings, ovipositors, etc. There are usually compound eyes and simple ocelli as well. The genital ducts open at the end of the body. The average habit is an intense activity. As this class is a very large one, we shall revise its characteristics first in general terms, and then as illustrated in the common cockroach.

Form.—The body of an adult insect may be divided into three distinct regions:—

1. The undivided head, which consists of at least three fused segments, as it bears three pairs of appendages.
2. The median thorax, divided into pro-, meso-, and meta-thoracic segments, each with a pair of legs, the two last with wings.
3. The abdomen with about eleven rings, usually without trace of limbs.

But this is only the crude anatomy of form. You must think of the long dragon-fly with outspread wings, and of the compact cockchafer, of the thin-waisted wasps and long-bodied butterflies, of house-fly and cricket, of large moths and beetles, and the almost invisible insect parasites.

Appendages.—Insects "feel their way," test food, and apparently communicate impressions to one another by means of a pair of jointed feelers or antennæ, situated in front of the head. Unlike the organs of a similar name in

Crustaceans, the antennæ are not ranked among the appendages strictly so-called. This is no pedantic distinction, but rests on the fact that their development is different from that of the jaws and legs.

It was a step of some importance in morphology when Savigny showed that the three pairs of appendages about the mouth were homologous with the other appendages, *i.e.*, were masticatory legs.

(1.) Furthest forward lie two *mandibles*, the biting and cutting jaws. These are single-jointed, and thus differ from the organs of the same name in the crayfish, which bear a three-jointed palp in addition to the hard basal part. In those insects which suck and do not bite, *e.g.*, adult butterflies, the mandibles are reduced.

(2.) Next in order is the *first pair of maxillæ*. Each maxilla consists of a basal piece (protopodite), an inner fork (endopodite), and an outer fork (exopodite). I use these names from Crustacean terminology, after the example of Marshall and Hurst. The entomologists divide the protopodite into a lower joint the *cardo*, and an upper the *stipes*, the endopodite into an internal *lacinia*, and an external *galea*, while the exopodite is called the maxillary palp.

(3.) The last pair of oral appendages or *second maxillæ* are partially fused, and form what is called the *labium*. The lower and upper joints of their fused protopodites are called *submentum* and *mentum*; the endopodites on each side are double as in the first maxillæ, and consist of internal *lacinia* and external *paraglossa*; the exopodites are called the *labial palps*.

The three pairs of thoracic legs consist of many joints, are usually clawed and hairy at their tips, and vary greatly according to their uses. Think, for instance, of the hairy feet by aid of which the fly runs up the smooth window-pane, of the muscular limbs of grasshoppers, of the lank length of those which characterise "daddy-long-legs," of the pollen-baskets on bees, of the oars of water-beetles. In identifying insects from a book it is needful to recognise the joints of the legs by the names which entomologists have transferred to them from human osteology, viz., the superior coxa with projecting trochanter, the stout femur, the tibia, and finally numerous tarsal joints.

Wings are flattened hollow sacs, which grow out from the two posterior rings of the thorax. They are moved by muscles, and traversed by "veins" or "nervures," which include air-tubes, nerves, and vessel-like continuations of the body-cavity. Most insects have two pairs, but many sluggish females and parasites like lice and fleas have lost them. On the other hand, there is no reason to believe that the very simplest wingless insects, known as Collembola and Thysanura, ever had wings. There are many interesting differences in regard to wings in the various orders of Insects. Thus in beetles the front pair form wing-covers or elytra, in the little bee-parasites—Strepsiptera—they are twisted rudiments, in flies the posterior pair are small knobbed stalks (halteres or balancers), in bees the wings on each side are hooked together. When the insect is at rest, the wings are usually folded neatly on the back; but dragon-flies, and others keep them expanded, butterflies raise them like a single sail on the back, moths keep them flat. Many wings bear small scales or hairs and are often brightly coloured. Professor Eimer maintains that the arrangement of the nervures and the colouring of butterfly wings are certain marks of the progress and relationships of species. It is well known that the colours also vary with sex, climate, and surroundings. Most interesting are those cases in which the colours of an insect harmonise exactly with those of its habitat, or make it a mimetic copy of some more successfully protected neighbour.

As to the origin of wings, this at least should be remembered, that in many cases they are of some use in respiration as well as in locomotion. Seeing that the power of flight is evidently an accomplishment which the original insects did not possess, it seems to me very likely that wings were originally respiratory outgrowths, which by-and-by became useful for aërial locomotion. This view is consistent with an idea, which grows in favour with evolutionists, that new organs develop by the predominance of some new function in organs which had some prior significance. Moreover, we can fancy that an increase in respiratory efficiency brought about by the outgrowths in question would quicken the whole life, and would tend to raise insects into the air, just as terrestrial insects can be made to frisk and jump when

placed in a vessel with relatively more oxygen than there is in the atmosphere. Finally, we must note that the aquatic larvæ of some insects, *e.g.*, may-flies, have a series of respiratory outgrowths from the sides of the abdomen, the so-called "tracheal-gills," which in origin and appearance are like young wings.

Insects excel in locomotion. "They walk, run, and jump with the quadrupeds; they fly with the birds; they glide with the serpents; and they swim with the fish." They beat the elastic air with their wings, and though there cannot be so much complexity of movement as in birds where the individual feathers move, the insect wing is no rigid plate, and its up and down motions are complex. They can soar rapidly, but their lightness often makes horizontal steering difficult. The wind often helps as well as hinders them; thus the insects which fly in and out of the windows of express trains are probably in part sucked along. Marey calculates the approximate number of wing-strokes per second at 330 for the fly, 240 for the humble-bee, 190 for the hive-bee, 110 for the wasp, 28 for the dragon-fly, 9 for a butterfly. It has been found by well-regulated races that for short distances you may safely back a bee against a pigeon.

Skin.—As in other Arthropods, the epidermis (or hypodermis) of Insects forms a firm cuticle of chitin, which in the exigencies of growth has sometimes to be moulted. This cuticle is often finely marked so that the animal seems iridescent, and there are many different kinds of scales, hairs, and spines. Chitin is not favourable to the development of skin-glands, but most insects have "salivary glands," opening in or near the mouth, bees have wax-making glands opening on the abdomen, aphides have "honey-dew" tubes, not a few have poison bags, and many larvæ besides silk-worms have organs from which are exuded the threads of which a cocoon is made.

Muscular System.—In very active animals like Insects, we of course find a highly developed set of rapidly contracting striped muscles. These work the wings, the legs, and the jaws. The resulting movements have this further significance that they help in the respiratory interchange of gases, and in the circulation of the blood.

Nervous System.—It is often remarked as marvellous that

ants and bees, with brains smaller than pin-heads, should be so clever. The more we know about an ant, "the more the wonder grows, so small a head should carry all it knows," or seems to know. But these statements imply forgetfulness of the relative size of brain to body, and tend moreover to exaggerate the importance of mere size. The complexity of a brain is the important fact, not its size, and there is no doubt that the cleverer insects (ants, bees, and wasps), have more complex brains than the others. As in other Arthropods, the nervous system consists (*a*) of a dorsal brain or supra-œsophageal ganglionic mass, and (*b*) of a double ventral nerve-cord with a number of paired ganglia of which the most anterior (the sub-œsophageal) are linked to the brain by a ring-commissure around the gullet, and (*c*) of nerves given off from the various ganglia to the sense-organs, the alimentary canal, and the other organs. In many of the higher insects the ganglia of the ventral nerve-cord are in some degree concentrated, and the adults are usually more centralised than the larvæ.

Sensory structures.—Animals so much alive as Insects, and in surroundings so stimulating as many of them enjoy, have naturally highly developed sense-organs.

Two compound eyes are present on the head of all adults except the primitive Collembola, the degenerate lice, the likewise parasitic fleas, and blind insects which live in caves or other dark places. Compound eyes vary considerably in structure, and it is not certain to what extent they form definite images of things. Each eye contains a large number of similar elements, in each of which we can distinguish (1) a cuticular or corneal facet, (2) a glassy lens-like portion, (3) a retinal portion in association with which are fibres from the optic nerve, and there are also pigmented cells between the elements.

Simple eyes or ocelli are present in addition to the compound eyes in the adults of many insects, *e.g.*, ants, bees, and wasps; they occur without the accompaniment of compound eyes in Collembola, lice, and fleas, and they are usually the only eyes possessed by larvæ. They have only one lens (monomeniscous), whereas the compound forms have many lenses (polymeniscous). Their structure varies greatly, and their use is very uncertain.

Auditory (or chordotonal) organs have been found in all orders of Insects (except as yet the Thysanoptera), and occur both in the larvæ and in the adults. Their essential structure is as follows: a nerve ends in a centre or ganglion near the skin, some of the cells of this ganglion grow out into long sensitive rods enclosed in a tiny sheath, the rods are directly or indirectly connected with epidermis above them. "They are found in groups of 2–200 in various parts of the body, antennæ, palps, legs, wings, in the halteres of Diptera, and upon the dorsal aspect of the abdomen." Quite different from these, and occurring in flies alone, on the hind end of the larva, or at the base of the adult's feelers, are little bags with fluid in which clear globules float. We do not know how much or how little Insects hear, but the "song" of male Cicadas and crickets does not fall on deaf ears.

In addition to the "eyes" and "ears" there are innervated hairs (tactile, tasting, olfactory) on the antennæ and mouth-parts of many insects. Not a few have been shown to possess a diffuse or dermatoptic sense, by which, for instance, they can, when blinded, find their way out of a dark box.

Many Insects produce sounds which often express a variety of emotions. We hear the whirr of rapidly moving wings in flies, the buzz of leaf-like structures near the openings of the air-tubes in many Hymenoptera, the scraping of legs against wing-ribs in grasshoppers, the chirping of male crickets which rub one wing against its neighbour, the piping of male Cicadas which have a complex musical instrument, the voice of the death's-head-moth which expels air forcibly from its mouth. The death-watch taps with his head on foreign objects, as if knocking at the door behind which his mate may be hidden. In some cases the sounds are simply automatic reflexes of activity; in many cases they serve as alluring love-songs, and they may also serve as expressions of fear and anger, or as warning alarms.

Alimentary System.—The diet of Insects is very varied. Some, such as locusts, are vegetarian, and destroy our crops; others are carnivorous (we need not specify the homœopathist's leech) and suck the blood of living victims, or devour the dead; the bees flit in search of nectar from flower to flower, while the ant-lion lurks in his pit of sand for any unwary stumbler; the termites gnaw decaying wood, and

even a wooden leg may crumble before their jaws; some ants keep aphides as cows ("vaccæ formicarum," Linnæus called them), whose sweet juices they lick; and a great number of larvæ devour the flesh and vegetables in which they are born.

It is important to have some vivid idea of the diversity of diet, for the many modifications of mouth organs, in beetle and bee, in caterpillar and butterfly, as well as differences in the alimentary canal itself, are associated with the way in which the insect feeds.

For purposes of classification, the following distinctions in regard to the mouth organs are very useful:—

(*a*) The mouth parts may be similar in all stages of life, and adapted for biting. In this case the term MENOGNATHA (*i.e.*, permanently jawed) is applied:—
e.g., to earwigs, may-flies, dragon-flies, the cockroach order (Orthoptera), the beetle order (Coleoptera).

(*b*) The mouth parts may be similar in all stages of life, and adapted for sucking. In this case the term MENORHYNCHA (*i.e.*, permanently with a sucking proboscis) is applied:—
e.g., to bugs of all sorts (Rhynchota or Hemiptera).

(*c*) The mouth parts may be adapted for biting in the larva, for sucking in the adult. In this case the term METAGNATHA (*i.e.*, with changed jaws), is applied:—
e.g., to butterflies and moths, flies and fleas.

The alimentary canal consists of fore-gut, mid-gut, and hind-gut, of which the mid-gut is endodermic and the result of the original gastrula-cavity (archenteron), whereas the other two regions are fore and hind invaginations of the ectoderm, and therefore lined by a chitinous cuticle.

The fore-gut conducts food, and includes mouth-cavity, pharynx, and œsophagus, the latter being often swollen into a storing crop, or continued into a muscular gizzard with grinding plates of chitin.

The mid-gut is digestive and absorptive, often bearing a number of glandular outgrowths or cæca, and varies in length (in beetles at least) in inverse proportion to the nutritive and digestive quality of the food.

The hind-gut is said to be partly absorptive, but is chiefly

a conducting intestine, often coiled and terminally expanded into a rectum with which glands are frequently associated.

In association with the alimentary canal are various glands :—

(*a*) The salivary glands, which open in or near the mouth. They are usually paired on each side, and provided with a reservoir. They arise as invaginations of the ectoderm near the mouth. Their secretion is mainly diastatic in function, *i.e.*, it changes starchy material into sugar by means of a ferment. Along with these may be ranked the "spinning glands" of caterpillars, etc., which also open at the mouth. They secrete material which hardens into the threads used for the cocoon.

(*b*) From the beginning of the mid-gut, blind outgrowths sometimes arise (in some Orthoptera, etc.), which are probably digestive. They are sometimes called pyloric cæca. In other cases (some beetles) there may be more numerous and smaller glandular outgrowths on the external wall of the mid-gut.

(*c*) From the hind-gut arise numerous fine Malpighian tubes, which are certainly excretory in function.

Respiratory System.—When we watch an insect—say a drone-fly resting on a flower—we can observe panting movements in the abdominal region. These movements are of the greatest importance in respiration. For all through the body there is a system of branching air-tubes (tracheæ) which open to the exterior by special apertures (stigmata) often guarded by hairs, and when the abdomen contracts, some of the air in these tubes is driven out, while the expansion of the body sucks air in. But the exchange of gases between the tissues and the tracheæ, and between the tracheæ and the atmosphere, is probably, for the most part, a slow diffusion.

The tracheæ seem to arise as tubular ingrowths of skin, and primitively each segment probably contained a distinct pair. But their number has been reduced, and many are often connected into a system. With the doubtful exception of one of the primitive Collembola, and the certain exception of caterpillars, no insects have any tracheal openings in the head region. There are rarely more than two pairs in the thorax, there are often six to eight pairs in the abdomen, the

maximum total is ten. Each trachea is kept tense throughout the greater part of its course by internal chitinous thickenings, which apparently have a spiral course. The branches of the tracheæ penetrate into all the organs of the body, carrying oxygen to every part. The very efficient respiration of insects must be kept in mind in an appreciation of the general activity of their life.

As the conditions of larval life are often different from those of the adult insects, the mode of respiration may also differ in details. Some of these differences may be summarised.

In insects without marked metamorphosis, and even in some beetles in which the metamorphosis is complete, the young insect and the adult both breathe by tracheæ with open stigmata. Both are said to be "holopneustic."

When the larvæ live in water, the tracheal system is closed, otherwise the creatures would drown. This closed condition is termed "apneustic." These larvæ (of dragon-flies, may-flies, and some others) breathe by "tracheal gills"—little wing-like outgrowths from the sides of the abdomen, rich in tracheæ—or by tracheal folds within the rectum, in and out of which water flows. In either case an interchange of gases between the tracheæ and the water takes place. In adult aërial life, the tracheæ of the body acquire stigmata, and the insect becomes "holopneustic."

In most insects with complete metamorphosis, the larva (*e.g.*, caterpillar or grub) has closed stigmata on the last two segments of the thorax (those which will bear wings), but there is a pair of open stigmata on the prothorax. In the adult the reverse is true.

There are some other modifications, witness what obtains in the parasitic larvæ of some flies, *e.g.*, gad-flies. In these the stigmata are open only at the ends of the body. In all cases, however, the stigmata of the adult are already present as rudiments in the larva, though they may not open till adolescence is over.

Circulatory System.—As the respiratory system is very efficient, establishing the possibility of gaseous interchange between the inmost recesses of the body and the external medium, it is natural that the blood-vascular system should not be highly developed. Within a dorsal part of the body-

cavity, known as the pericardium, the heart lies, swayed by special muscles. It is a long tube, usually confined to the abdomen, usually of eight chambers, with paired valvular openings on its sides, through which blood enters from the pericardium. The blood is driven forwards, the posterior end of the heart being closed, and there is usually an anterior aorta or main blood-vessel. But for the most part the blood circulates in spaces within what is commonly called the body-cavity. Such a circulation is often described as lacunar. The blood may be colourless, yellow, red, or even greenish, and in some cases hæmoglobin, the characteristic blood-pigment of Vertebrates, has been detected. The cells of the blood are amœboid.

Body-Cavity.—One is apt to use this term in two senses—for the primitive body-cavity or cœlome, and for the apparent body-cavity of the adult. In discussing the development of *Peripatus*, Sedgwick notes the following characteristics of a true cœlome:—It is a cavity which (1) does not communicate with the vascular system, (2) does communicate by nephridial pores with the exterior, (3) has the reproductive elements developed on its lining, (4) develops either as one or more diverticula from the primitive enteron (or gut), or as a space or spaces in the unsegmented or segmented mesodermic segments. Now, in Arthropods the apparent body-cavity is not a true cœlome, it consists of a set of secondarily derived vascular spaces; it has been called a pseudocœle, or a hæmocœle. The true cœlome of Arthropods is very much restricted in the adult, all the more so that most Arthropods (*e.g.*, Insects) have no distinct nephridia.

But the apparent body-cavity in which the organs lie, and in which the blood circulates, is well-developed in Insects. It includes, *inter alia*, a peculiar fatty tissue, which seems to be a store of reserve material, which is especially large in young insects before metamorphosis, and is also interesting as one of the seats of "phosphorescence" in those insects which glow.

Excretory System.—Although no structures certainly homologous with nephridia have yet been demonstrated in Insects, the excretory system is well-developed. From the hind-gut (proctodæum), and therefore of ectodermic origin, arise fine tubes, or in some cases solid threads, which extend

into the apparent body-cavity. Their number varies from two (in some Lepidoptera for instance) to one hundred and fifty (in the bee). They twine about the organs in the abdominal cavity, and their excretory significance is proved by the fact that they contain uric acid.

Reproductive System.—Among Insects the sexes are always separate and often different in appearance. The males are more active, smaller, and more brightly coloured than the females. Darwin referred the greater decorativeness of the males to the sexual selection exercised by the females. The handsomer variations succeeded in courtship better than their rivals. Wallace referred the greater plainness of females to the elimination of the disadvantageously conspicuous in the course of natural selection. There is apparently truth in both views, and also in a third theory, in part accepted by Wallace, that the "secondary sexual characters" of both sexes are the natural and necessary expressions of their respectively dominant constitutions.

Reproductive Organs.

MALE.	FEMALE.
The paired Testes usually consist of many small tubes.	The paired Ovaries usually consist of many small tubes (ovarioles).
Two ducts (vasa deferentia), conducting spermatozoa (perhaps in part comparable to nephridia).	Two ducts (oviducts), conducting the ova (perhaps in part comparable to nephridia).
An unpaired terminal and ejaculatory duct, paired and with two apertures in Ephemerids only; sometimes formed by a union of the vasa deferentia, sometimes by an external invagination meeting the vasa deferentia.	An unpaired terminal region or vagina, paired, and with two apertures in Ephemerids; usually formed from an external invagination meeting the united ends of the oviducts.
From the vasa deferentia or from the ejaculatory duct, a paired or unpaired seminal vesicle for storing spermatozoa.	From the vagina, a receptaculum seminis for storing spermatozoa received from a male during copulation.
Various accessory glands, whose secretion sometimes unites the spermatozoa into packets or spermatophores.	Various accessory glands, *e.g.*, those which secrete the material surrounding the eggs.
Sometimes a copulatory penis.	Sometimes a special bursa copulatrix in the vagina.
Often external hard pieces.	Often external hard pieces, *e.g.*, ovipositor.

Some Peculiarities in Reproduction.

Many Insects, such as aphides, silk-moth, and queen-bee, are exceedingly prolific. The queen-termite goes on for a time laying thousands of eggs "at the rate of about sixty per minute"!

The store of spermatozoa received by the female, and kept within the receptaculum seminis, often lasts for a long time,—for two or three years in some queen-bees. Sir John Lubbock gives the remarkable instance of an aged queen-ant, which laid fertile eggs thirteen years after the last union with a male.

Parthenogenesis, or the development of ova which are unfertilised, occurs normally, for a variable number of generations, in two Lepidoptera and one beetle, in some coccus-insects and aphides, and in certain saw-flies and gall-wasps. It occurs casually in the silk-moth and several other Lepidoptera, seasonally in aphides, in larval life in some midges (*Miastor*, *Chironomus*), and partially or "voluntarily" when the queen-bee lays eggs which become drones. The unfertilised eggs of the hive-bee become drones, the fertilised become queens (perfectly sexual females) or workers (abortively sexual females), according to the richer or plainer diet given to the grubs. Parthenogenetic ova (in water-fleas, Rotifers, etc.), are believed to form only one polar body; the egg which becomes a drone forms two as usual, but the case of the bee is in several respects exceptional.

A few insects hatch their young within the body, or are "viviparous." This is the case with parthenogenetic summer aphides, a few flies, the little bee-parasites Strepsiptera, and a few beetles.

Development of the Ovum.—The tubes which compose the ovaries and lead into the oviducts start from thin filaments, the ends of which are usually connected on each side. Those thin filaments consist of indifferent germinal cells, all of them potential ova.

But in most cases only a minority of these cells become ova, the others become nutritive cells, which are absorbed by the ova, and follicle cells which line the walls of the ovarian tubes and help to furnish the egg-shells.

There may be, indeed, ovarian tubes without nutritive cells (*e.g.*, in Orthoptera), and then each tube is simply a bead-like row of ova, which become larger and larger as they recede from the thin terminal filaments and approach the oviducts. In other cases, the bead-like row consists of ova alternating with clumps of nutritive cells (*e.g.*, in Hymenoptera and Lepidoptera). In other cases, the nutritive cells mostly remain in the terminal region, but their products pass down to the receding ova.

As there are numerous ovarian tubes in each ovary, and as the same process of oogenesis is going on in each, a number of eggs are ready for liberation at the same time, and are simultaneously discharged into the oviduct of each side.

The ovum is not only furnished with yolk from the nutritive cells, it is also surrounded by a shell, which is formed in most cases by the follicle cells lining the ovarian tubes. The shell is firm and chitinous. It is pierced by one minute hole (micropyle), or by several. Through a micropyle a single spermatozoon finds entrance, sometimes (as in the cockroach) after moving round and round the surface of the shell in varying orbits.

Segmentation.—The segmentation which follows fertilisation is described as superficial or centrolecithal, the centre of the ovum being occupied by a core of relatively passive yolk with scattered nuclei. The result of segmentation is a sphere or ellipsoid of cells, and on the ventral surface of this, on what is specially designated the "ventral plate," the embryo begins to be mapped out. A long shallow invagination represents the gastrula, and establishes the (endodermic) mid-gut, and at the same time the mesoderm.

One of the most remarkable facts in the development is the formation of a double fold of blastoderm, arching over the ventral embryonic layer. The internal fold is called "amniotic," the outer "serous," from their resemblance to similar enswathing envelopes in the embryos of the higher Vertebrates. These folds do not, however, take any direct part in the development of the embryo. The same is probably true of the yolk, for though it segments around the nuclei which it contains, it seems to be eventually absorbed by the mid-gut.

Development of the Organs, etc.—The epidermis is formed by the ectoderm. From the epidermis arises the external chitinous cuticle. The muscles arise from mesoderm, which originates in connection with the invagination of the blastoderm, and is in great part divided into a double row of mesodermic segments. The appendages appear as paired bud-like outgrowths of the ectoderm and subjacent mesoderm. The brain arises as a paired ectodermic thickening on the head. It is connected at a very early stage with the double ventral nerve-cord, which has a similar origin along the ventral surface. In both cases there is necess-

arily an insinking from the surface. The eyes arise in part at least as invaginations of the skin.

The gut has a three-fold origin. The fore-gut (stomatodæum), and the hind-gut (proctodæum), are fore and hind invaginations of ectoderm; the mid-gut (mesenteron) is lined by endoderm, which seems to originate in the invagination of the blastoderm. It is doubtful, however, whether the yolk does not to some extent help to form the endoderm. The heart is formed from two dorsal rows of mesoderm cells. The tracheæ arise as ingrowths of the epidermis. The Malpighian tubules are outgrowths from the ectodermic hind-gut.

Metamorphosis of Insects.

(1) In the lowest Insects, namely, in the old-fashioned wingless Thysanura and Collembola, the hatched young are miniature adults. By gradual growth and after several moultings, they attain adult size.

Similarly the newly hatched earwigs, young of cockroaches and locusts, of lice, aphides, termites, and bugs, are very like the parents, except that they are sexually immature, and that there are no wings, which indeed are absent from some of the adults.

These insects are called *ametabolic*, *i.e.*, they exhibit no marked change or metamorphosis.

(2) In Cicadas there is slight but most instructive difference between larvæ and adults. The adults live among herbage, the young on the ground, and the diversity of habit has associated differences of structure, witness the burrowing fore-legs of the larva. Moreover, the larva acquires the characters of an adult after a quiescent period of pupation.

The differences between larva and adult are more striking in may-flies, dragon-flies, and the related Plecoptera (*e.g.*, *Perla*), for in these the larvæ are aquatic, with closed respiratory apertures, with tracheal gills or folds, while the adults are winged and aërial, and breathe by open tracheæ.

These insects are called *hemimetabolic*, *i.e.*, they have a partial or incomplete metamorphosis.

(3) Very different is the life-history of all other sets of Insects—ant-lions, caddis-flies, flies, fleas, butterflies and moths, beetles, ants and bees. From the egg there is

hatched a larva (maggot, grub, or caterpillar), which lives a life very different from the adult, and is altogether unlike it in form. The larva feeds voraciously, grows, rests, and moults. Having accumulated a rich store of reserve material in its "fatty body," it finally becomes for some time quiescent as a pupa, nymph, or chrysalis, often within the shelter of a cocoon. During this period there are great transformations; wings bud out, appendages of the adult pattern are formed, reconstruction of other organs is effected. Finally, out of the pupal husk emerges a miniature winged insect of the adult or imago type.

These insects are called *holometabolic*, *i.e.*, they exhibit a complete metamorphosis.

The typical larva is the caterpillar with limbs and distinct head; the "maggots" of flies, etc. (without distinct head or limbs), and the grubs of bees, etc. (with distinct head but without limbs) are somewhat degenerate. But this larva of holometabolic insects, technically called eruciform, is very different from that of most ametabolic and hemimetabolic insects, which is technically called campodeiform. For the latter is not worm-like, but rather like one of the lowly Thysanuran insects (*Campodea*),—with the regions of the body well-defined, with locomotor thoracic limbs, and with mouth-parts adapted for suction.

The larvæ of Insects vary enormously in habit and in structure, and exhibit numerous adaptations to conditions of life very different from those of the parent. Thus caterpillars, which are usually plump and tense, so that a peck from a bird's bill may cause them to bleed to death even if no immediate destruction befall them, are protectively adapted in many different ways. Their colours are often changed in harmony with those of their surroundings, some palatable forms are saved by their superficial resemblance to those which are nauseous, a few strike "terrifying attitudes," others are like pieces of plants.

But for our purpose it is perhaps more important to recall the differences between the respiration of some larvæ and that of the adult, between the apneustic larva of the dragon-fly, and the holopneustic winged tyrant. Likewise of great importance, and supplying a basis for classification, are the changes in connection with the mouth-organs. The main facts may be

summarised in a terse sentence from the monumental work of Rolleston and Hatchett Jackson ("Forms of Animal Life," Oxford, 1888). "The mouth parts may be similar in all stages of life, and then are either adapted for biting (*Menognatha*, *i.e.*, jaws persistent), or for sucking (*Menorhyncha*, *i.e.*, proboscis persistent; or else they are adapted in the larva for biting, in the adult for sucking, the change commencing in the pupa, and rarely affecting the larval stage (*Metagnatha*, *i.e.*, jaws changed)."

Internal Metamorphosis.—In Insects with no marked metamorphosis, or with an incomplete one merely, the organs of the larva develop gradually into those of the adult. But in Insects with complete metamorphosis, there is a marvellous internal reconstruction during the later larval, and especially during the quiescent pupal stage. Most of the larval organs are disrupted, and partially absorbed by amœboid cells, their débris being used in building new structures. Parts of larval organs which have not been highly specialised form the foundations of new adult structures. Of special importance are certain ingrowths of the larval skin (the epi- or hypodermis) which form what are called "imaginal discs," from which arise the wings, legs, and epidermis of the imago or perfect insect. The reconstruction is very thorough; most of the musculature, much of the tracheal system, part of the mid-gut, etc., are gradually replaced by the corresponding organs of the adult. Yet there is no abruptness; the absorption and replacement of organs is perfectly gradual.

General Life of Insects.

The average insect is active, but between orders (*e.g.*, ants, bees, and wasps *versus* aphides, coccus-insects, and bugs), between nearly related families, between the sexes (*e.g.*, male and female cochineal insect), between caterpillar and pupa, we read the constantly recurrent antithesis between activity and passivity.

The average length of life is short. Queen-bees of five years, queen-ants aged thirteen, are rare exceptions. In many cases death follows as the rapid nemesis of reproduction. But though the adult life is often very short, the total life

may be of considerable length, witness some Ephemerids which in their adult life of winged love-making may be literally the flies of a day, while their aquatic larval stages may have lived for two years or more.

The relation between the annual appearance of certain insects and that of the plants which they visit, the habits of hibernation in the adult or larval state, the occasional "dimorphism" between winter and summer broods of butterflies, should be noticed.

The prolific multiplication of many insects may lead to local and periodic increase in their numbers, but great increase is limited by the food-supply and the weather, by the warfare between insects of different kinds, by the numerous insects parasitic on others, by the appetite of higher animals,—fishes, frogs, ant-eaters, insectivores, and, above all, birds.

There is a great variety of protective adaptation. The young of caddis-flies are partially masked by their external cases of pebbles and fragments of stem; many caterpillars and adult insects harmonise with the colour of their environment; leaf-insects, "walking sticks," moss-insects, scale-insects, have a precise resemblance to external objects which must often save them; a humming-bird moth closely resembles a humming-bird, many palatable insects and larvæ have a mimetic resemblance to others which are nauseous or otherwise little likely to be meddled with. Many insects may be saved by their hard chitinous armour, by their disgusting odour or taste, by their deterrent discharges of repulsive formic acid, etc., by simulation of death, by active resistance with effective weapons.

Many flowers depend for cross-fertilisation upon insects which carry the pollen from one to another. Many insects depend for food on the nectar and pollen of flowers. Thus many flowers and insects are mutually dependent. But many insects injure plants, and many plants exhibit structures which tend to save them from attack. On the other hand, there may be "partnerships" between insects and plants—witness the "myrmecophilous" (ant-loving) plants which shelter a bodyguard of ants, by whom they are saved from unwelcome visitors. And again, the formation of galls by some insects which lay their eggs in plants, and the insect-

catching proclivities of some carnivorous plants, should be remembered.

Most insects are terrestrial and aërial, the majority live in warm and temperate countries, but they are represented almost everywhere, even above the snow line, in arctic regions, in caves. Even on the sea the "Challenger" explorers found the pelagic *Halobates*, a genus of bugs. The distribution of Insects is mainly limited by food-supplies and climate, for their powers of flight are often great, and their opportunities of passive dispersal by the wind, floating logs, etc., are by no means slight.

Many insects are more or less parasitic, either externally as adults, *e.g.*, fleas, lice, bird-lice, plant-lice, etc., or internally as larvæ, *e.g.*, the maggots of gad-flies on cattle, and a great number of borers within plants.

We need only mention Hessian-fly, Phylloxera, Colorado-beetle, Weevils, Locusts, to suggest many more which are of much economic importance as injurious insects. On the other hand, our indebtedness to hive-bee and silk-moth, to cochineal and lac insects, to those which destroy injurious insects, and to those which carry pollen from flower to flower, is obvious.

Finally, we must at least mention that in ants, bees, wasps, and termites, we find illustration of various grades of social life, and marvellous exhibitions of instinctive skill and also of genuine intelligence.

A Type of Insects—*Periplaneta* (or *Blatta*)— The Cockroach.

The cockroaches found in Britain are immigrants either from the East (*P. orientalis*), or from America (*P. americana*). They are omnivorous in their diet, and active in their habits, but they hide during the day, and feed at night. They are ancient insects, for related forms seem to have occurred in Silurian ages; they are average types of Insects, not being highly specialised. Their position is among the Orthoptera, *i.e.*, in the same order as locusts and grasshoppers. The young develop without metamorphosis.

External Characters.

THE HEAD.	APPENDAGES OF THE HEAD.	OTHER STRUCTURES ON THE HEAD.
It is vertically elongated and separated from the thorax by a neck.	1. A pair of stout toothed mandibles working sideways. 2. The first maxillæ, each consisting (*a*) of a basal piece or protopodite with two joints—a basal cardo, a distal stipes ; (*b*) of a double endopodite borne by the basal piece, and consisting of an inner lacinia and a softer outer galea ; (*c*) of an exopodite or maxillary palp also borne by the basal piece, and consisting of five joints. 3. The second pair of maxillæ, fused together as the "labium," consisting (*a*) of a fused basal piece or protopodite with two joints—a basal submentum; a smaller distal mentum ; on each side this protopodite bears (*b*) a double endopodite (ligula) consisting of an inner lacinia, and an outer paraglossa ; (*c*) an exopodite or labial palp, consisting of three joints.	The antennæ (probably not homologous with appendages), long, slender, many-jointed, tactile. The large black compound eyes. The "upper lip" or labrum, in front of the mouth. The white oval patches near the bases of the antennæ, possibly sensory.
THE THORAX.	**THE APPENDAGES OF THE THORAX.**	**OTHER STRUCTURES ON THE THORAX.**
It consists of three segments:— (*a*) prothorax, (*b*) mesothorax, (*c*) metathorax. (Each segment is bounded by a dorsal tergum, and ventral sternum.)	(*a*) First pair of legs. (*b*) Second pair of legs. (*c*) Third pair of legs. Each leg consists of many joints—a basal "coxa" with a small "trochanter" at its distal end, a "femur," a "tibia," a six-jointed tarsus or foot ending in a pair of claws.	(*b*) A pair of elytra or wing-covers (modified wings) ; rudimentary in female of *P. orientalis*. (*c*) A pair of membranous wings, sometimes used in flight, folded when not in use, absent in female of *P. orientalis*. Between the segments of the thorax are two pairs of respiratory apertures or stigmata.
THE ABDOMEN.	**APPENDAGES (?) OF THE ABDOMEN.**	**OTHER STRUCTURES ON THE ABDOMEN.**
It consists of ten distinct segments, with terga and sterna as in the thorax.	Two cigar-shaped tactile anal cerci, attached under the edges of the last tergum, are possibly relics of abdominal appendages. The ninth sternum of the male bears a pair of styles, possibly relics of appendages. Both sexes have complex hard structures (gonapophyses) beside the genital apertures. They are possiby relics of appendages, but this is not very likeiy.	A pair of stigmata occur between the edges of the terga and sterna in the first eight abdominal segments. There are therefore twenty stigmata in all. The anus is terminal, beneath the tenth tergum of the abdomen ; a pair of "podical plates" lie beside it. The genital aperture is terminal, ventral to the anus. The opening of the spermatheca — the female's receptacle for spermatozoa—lies on the ninth sternum of the abdomen.

The *skin* consists of an external chitinous cuticle and a subjacent cellular layer—the epidermis or hypodermis—from which the cuticle is formed. The newly hatched cockroaches are white, the adults are dark brown. Moulting, which involves a casting of the cuticle, of the internal lining of the tracheæ, etc., occurs some seven times before the cockroach attains in its fifth year to adult maturity.

The *muscles*, which move the appendages, and produce abdominal movements essential to respiration, are markedly cross-striped.

Nervous System.—A pair of supra-œsophageal or cerebral ganglia lie united in the head. As a brain, they receive impressions by antennary and optic nerves. By means of a paired commissure surrounding the gullet, they are connected with a double ventral chain of ten ganglia. Of these, the first or sub-œsophageal pair are large, and give off nerves to the mouth parts, etc.; from each of the three pairs in the thorax and the six pairs in the abdomen, of which the last pair are largest, nerves are given off to adjacent parts. From the œsophageal commissures two visceral nerves are given off, which form in a somewhat complex manner the innervation of gullet, crop, and gizzard. Besides the large compound eyes, there are other sensory structures—some of the hairs on the skin, the maxillæ (to some extent organs of taste), the antennæ (tactile and olfactory), the anal cerci (tactile), and possibly the oval white patches on the head.

Alimentary System.—(1) The fore-gut (stomatodæum) is lined by a chitinous cuticle continuous with that of the outer surface of the body. It includes (*a*) the buccal or mouth-cavity, in which there is a tongue-like ridge, and into which there opens the duct of the salivary glands; (*b*) of the narrow gullet or œsophagus; (*c*) of the swollen crop; (*d*) of the gizzard or proventriculus with muscular walls, six hard cuticular teeth, and some bristly pads.

There is a pair of diffuse salivary glands on each side of the crop, and between each pair of glands a salivary receptacle. The ducts of each salivary gland unite on each side, the two ducts thus formed unite in a median duct, and this unites with another median duct formed from the union of the ducts of the receptacles. The common duct opens into the mouth.

(2) The mid-gut (mesenteron) is lined by endoderm. It is short and narrow, and with its anterior end seven or eight club-shaped digestive outgrowths ("hepatic" cæca) are connected. These seem to have a pancreatic function.

(3) The hind-gut (proctodæum) is lined by a chitinous cuticle. It is convoluted and divided into narrow ileum, wider colon, and dilated rectum with six internal ridges. From the beginning of the ileum, the excretory Malpighian tubules are given off.

Respiratory System.—The tracheal tubes, which have ten pairs of lateral apertures or stigmata, ramify throughout the body.

Circulatory System.—The chambered heart lies along the mid dorsal line of abdomen and thorax. It receives blood by lateral valvular apertures from the surrounding pericardial space, and drives it forwards by a slender aorta. The blood circulates, however, within ill-defined spaces in the body.

The *Excretory System* consists of sixty or so fine (Malpighian) tubules, which rise in six bundles from the beginning of the ileum, and twine through the "fatty body" and in the abdominal cavity.

Reproductive System

Of the Male.	Of the Female.
The testes are paired organs, surrounded by the fatty-body below the 5th and 6th abdominal terga. They atrophy in the adult.	The ovaries are paired organs, in the posterior abdominal region, each consisting of eight ovarian tubes. These are bead-like strings of ova at various stages of ripeness.
From the testes, two narrow ducts or vasa deferentia lead to two seminal vesicles.	From the ovarian tubes of each side, eight eggs pass into a short wide oviduct.
These seminal vesicles (the "mushroom-shaped gland") open into the top of the ejaculatory duct.	
This duct opens on the 10th sternum. Beside the aperture there are copulatory structures (gonapophyses). With the ejaculatory duct a gland is associated.	The two oviducts unite and open in a median aperture between the 8th and 9th abdominal sterna. Beside the aperture are hard structures (gonapophyses) which help in the egg-laying. Here also a pair of "colleterial" glands pour out their cementing secretion by two apertures. The spermatheca is a paired sac with a single aperture on the 9th abdominal sternum.

Sixteen ova, one from each ovarian tube, are usually enclosed within each egg-capsule. The latter is formed from the secretion of the colleterial glands. Each egg is enclosed in an oval shell, on which there are several little holes (micropyles), through one of which a spermatozoon enters. Spermatozoa, from the female's store within the spermatheca, are included in the egg-capsule. The development may be inferred from what has been said in regard to that of Insects in general, and it has already been mentioned that there is no metamorphosis.

History.—Insects must have appeared comparatively early, for remains of a cockroach-like form have been found even in Silurian strata. The higher forms with complete metamorphosis appear much later (*e.g.*, beetles in the Carboniferous), but it is likely that the Palæozoic Insects were mostly generalised types, prophetic of, rather than referable to our modern orders.

As to the pedigree of Insects, the wingless Collembola and Thysanura are doubtless primitive. They lead us back to some of the less specialised Myriopods (*e.g.*, *Scolopendrella*), back further to *Peripatus*, which links the Tracheate to the Annelid series. But though the wingless primitive Insects, the simple types of Myriopod, and *Peripatus*, may represent ascending grades of evolution; what the precise path has been we do not know, nor are we much wiser about the relationships among the different orders of Insects.

Classification of Insects (after Brauer and Lang).

PTERYGOTA, Winged Insects (excepting some degenerate forms).	Order 16. *Hymenoptera.* Ants, bees, wasps, gall-flies, saw-flies, etc. Menogn. or Metagn., or a sort of compromise between these states. Usually with four transparent wings. Larvæ are footless grubs except in some wasps.
C. METABOLA (*i.e.*, with complete metamorphosis)	Order 15 *Lepidoptera.* Butterflies and moths. Metagn. Two pairs of uniform, scaly, wings. Larva—a caterpillar.
either MENOGNATHA (*i.e.*, always with biting jaws)	Order 14. *Diptera.* Two-winged flies. Housefly, gad-fly, midge, gnat. Metagn., but sometimes with power of biting. Two anterior transparent unfolded wings, and posterior "balancers" or "halteres." Larva—usually a footless maggot, without a distinct head.
or METAGNATHA (*i.e.*, biting jaws replaced by sucking apparatus).	Order 13. *Siphonaptera* or *Aphaniptera.* Fleas. Metagn., but also with power of piercing. No wings. No compound eyes. Ectoparasitic. Larva—a footless maggot.
	Order 12. *Coleoptera.* Beetles. Menogn., rarely Metagn. Fore wings modified into wing-covers, hind wings folded when not in use. Larvæ very diverse, generally with feet. The little bee-parasites Strepsiptera are probably allied.
	Order 11. *Trichoptera.* Caddis-flies. Menogn. Hind wings usually larger than fore wings, both folded like fans. The body is hairy, rarely scaly. The larvæ are somewhat caterpillar-like, usually live in water within special cases, and are apneustic.
	Order 10. *Panorpata.* Scorpion-flies. Menogn. Two pairs of narrow membranous wings or sometimes none. Larva—like a caterpillar.
	Order 9. *Neuroptera.* Ant-lions and lace-winged flies. Menogn. Two pairs of glassy wings with many nervures. Larvæ sometimes live in water, and have tracheal gills.

B. AMETABOLA (*i.e.*, no metamorphosis). MENORHYNCHA (*i.e.*, with persistent suctorial organs).	Order 8.	*Rhynchota* or *Hemiptera*. *e.g.*, Aphides, coccus-insects, cicadas; bugs, water-scorpions, lice. (The male coccus-insects have a complete metamorphosis.) The mouth-parts are adapted for sucking and for slight piercing. Two pairs of wings or none. The parasitic forms have no compound eyes, and are in several respects degenerate.
A. AMETABOLA (*i.e.*, with no metamorphosis).	Order 7.	*Thysanoptera*, *e.g.*, *Thrips*. Ametab. Suctorial mouth organs. Wings very narrow, often rudimentary or absent. Only three or four pairs of stigmata. Concentrated nervous system.
and HEMIMETABOLA (*i.e.*, with incomplete metamorphosis)	Order 6.	*Corrodentia*, *e.g.*, Bird-lice, termites. Ametab. Mouth parts adapted for biting. Wings often wanting. The bird-lice have no compound eyes.
MENOGNATHA (*i.e.*, with persistent biting jaws).	Order 5.	*Orthoptera*, *e.g.*, Cockroach, locust, cricket, mole-cricket, "walking stick," "walking leaf." Ametab. Mouth parts adapted for biting. Anterior wings usually shorter and firmer than those behind, or modified into wing-covers. Both pairs are sometimes absent.
	Order 4.	*Plecoptera*, *e.g.*, *Perla*. Hemimetab. Mouth parts adapted for biting. Two pairs of large wings or none. The larvæ live in water, and breathe by tracheal gills, which often persist in the adult.
	Order 3.	*Odonata*, Dragon-flies. Hemimetab. Mouth-parts adapted for biting. Two pairs of large unfolded wings. The larvæ live in water, and breathe by tracheal gills or folds.
	Order 2.	*Ephemerida*, May-flies. Hemimetab. Mouth-parts of adult somewhat degenerate, and rarely used. Fore wings large, hind wings small or absent. Larvæ live in water, breathe by tracheal gills, and have biting mouth organs.
	Order 1.	*Dermaptera*, Earwigs. Ametab. Mouth-parts adapted for biting. Anterior wings small, hind wings large but folded both longitudinally and crosswise. Posterior forceps.
APTERYGOTA. Primitive Wingless Insects.	Order 2.	*Collembola*, Springtails, *e.g.*, *Podura*, *Smynthurus*.
	Order 1.	*Thysanura*, *e.g.*, *Campodea*, *Lepisma*.

DIAGRAM XIII.

PERIPATUS, MYRIOPODS, AND INSECTS.

At the base is a diagram of *Peripatus*, with a nephridium to the right, and a branching trachea to the left.

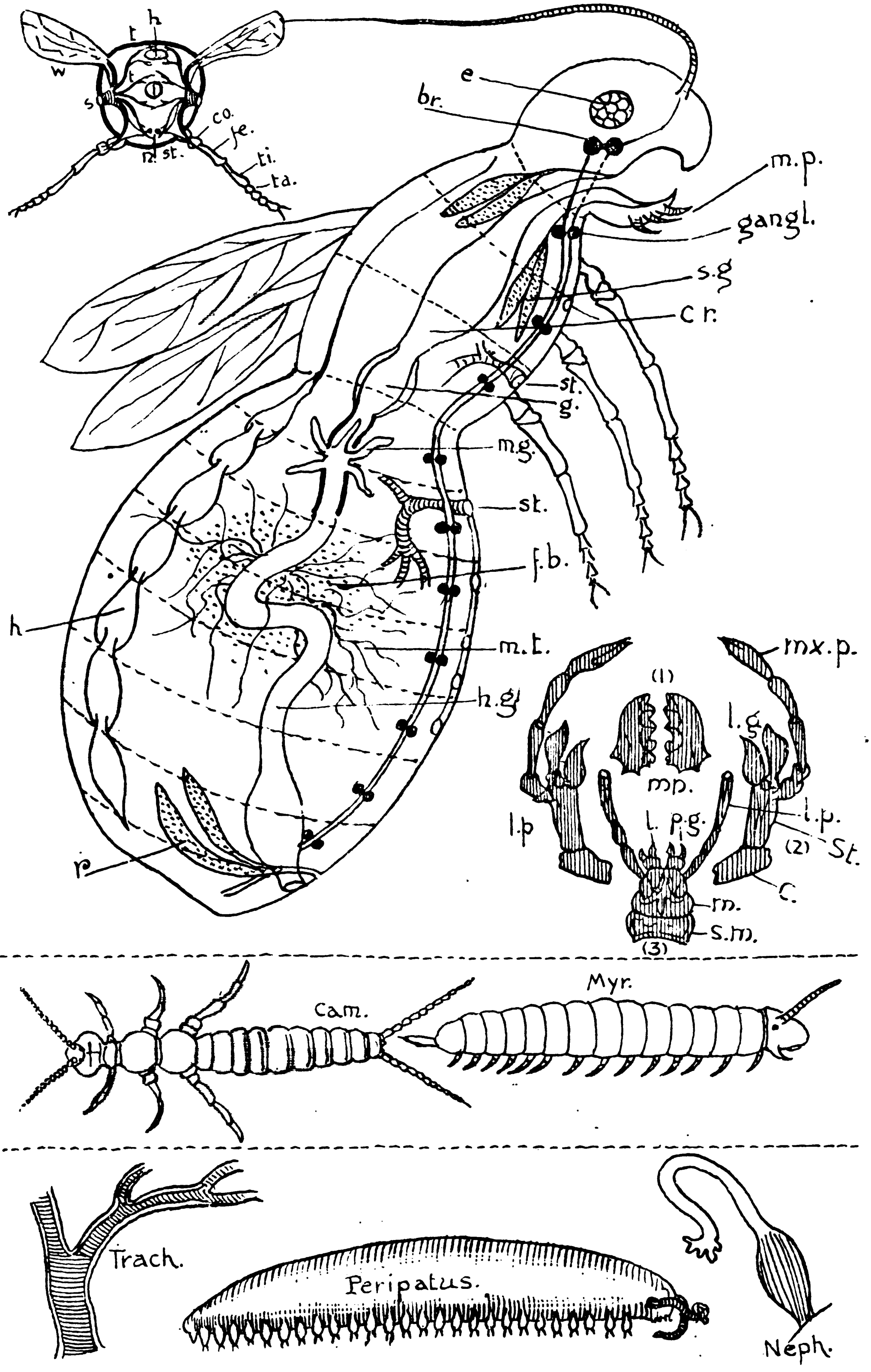
Above there is a diagrammatic representation of a simple Myriopod (*Myr.*), and one of the primitive wingless insects—*Campodea* (*Cam.*).

The diagrammatic figure of an "ideal insect" shows the head with antennæ (*ant.*), eyes (*e.*), mouth and mouth-parts (*m. p.*); the thorax with legs and wings; the abdomen with stigmata (*st.*); the dorsal heart (*h.*); the reproductive organs and ducts (*r.*); the gut with gullet and salivary glands (*s. g.*), crop (*cr.*), gizzard (*g.*), stomach and digestive cæca (*m. g.*), intestine with Malpighian tubules (*m. t.*), the hind-gut (*h. g.*), the fatty body (*f. b.*), the brain (*br.*), the ring round the gullet, the sub-œsophageal ganglia (*gangl.*), and the ventral chain are also shown.

The mouth-parts of the cockroach are shown:—(1) the mandibles (*mn.*); (2) the first maxillæ, with cardo (*c.*), stipes (*st.*), palp (*mx. p.*), galea (*g.*), lacinia (*l.*); (3) the second maxillæ, with sub-mentum (*s. m.*), mentum (*m.*), palp (*l. p.*), paraglossa (*pg.*), lacinia (*l.*).

At the left upper corner is a cross section of the thorax of an insect, showing the dorsal tergum, the ventral sternum (*st.*), the heart (*ht.*), the gut (*i.*), the stigmata (*s.*), and tracheæ (*t.*), the ventral nerve-cord (*n.*), the wings (*w*), the legs with coxa (*co.*), femur (*fe.*), tibia (*ti.*), tarsal joints (*ta.*).

Tracheata.



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(3)
Cam.
Myr.
Trach.
Peripatus.
Neph.

Class ARACHNOIDEA—Spiders, Scorpions, Mites, etc.

The class Arachnoidea is far from being a coherent unity. Its subdivisions are numerous and diverse, and the statement of general characters is consequently difficult. For the majority, the following hold true.

The anterior segments, to the number of seven or so, are fused into a cephalothoracic region, which bears six pairs of appendages. Though the most anterior of these appendages is often turned in front of the mouth, there are no pre-oral outgrowths comparable to the antennæ of Insects and Myriopods. The first two pairs of appendages (cheliceræ and pedipalps) generally have to do with seizing and holding the food, the four other pairs are walking-legs. But although six pairs occur in most, there may be more or less. It is equally unsatisfactory to say that the abdomen is generally but not always without appendages, that it may be segmented or unsegmented, that it is generally distinct from, but may be fused to the cephalothorax. So the respiration may be by tubular tracheæ alone, or by chambered tracheæ (pulmonary sacs) alone, or by both combined, or (in *Limulus*) by peculiar gill-like structures. In the tracheate forms (*i.e.*, in almost all except *Limulus*), there are never more than four pairs of stigmata. An elongated dorsal heart usually lies in the abdomen.

SYSTEMATIC SURVEY OF ARACHNOIDEA.

Order 1. SCORPIONIDÆ. Scorpions.

The Scorpions have a well-developed stinging organ. The venom is lodged in the tip of the "tail," which they bend upwards and wave about when excited. Suddenly straightening it, they strike downwards. In man the poison seems to act chiefly on the red blood-corpuscles, and though never or very rarely fatal the consequences are often serious. "The best remedy is ammonia applied externally, and also administered in small doses internally."

Scorpions are restricted to warm countries. They lurk under stones, etc., and are active at night. The *Scorpio afer*

of the East Indies attains a length of six inches, but the majority are much smaller. They feed on the blood and juices of Insects and other small animals. It is often said that scorpions will commit suicide when surrounded by fire or when otherwise fatally threatened, but to this it is answered—first, that their poison does not affect themselves; secondly, that they do not sting themselves; thirdly, that they could not if they would!

The body consists of an unsegmented cephalothorax and a twelve-segmented abdomen. The abdomen includes two distinct regions,—a broad anterior seven-segmented "mesosoma," and a narrow five-segmented "metasoma," at the end of which there is a post-anal "telson" or sting containing a double poison gland opening at the sharp tip. There is a firm cuticle of chitin; and an interesting internal piece of skeleton (the entosternite) partly chitinoid, but also resembling fibro-cartilage, lies between the anterior end of the gut and the central nervous system, and serves for the attachment of muscles.

The appendages are—

(1) Small chelate cheliceræ or falces just above the mouth.

(2) Large chelate pedipalps which seize the prey. In some cases they produce sounds by rasping.

(3–6) Four pairs of walking-legs. The basal joints of the first two pairs of legs are utilised in connection with the mouth.

Apparently equivalent to a pair of appendages is a small double lid or operculum covering the genital aperture on the first abdominal segment.

Apparently of the nature of appendages are the comb-like, apparently tactile, pectines on the second abdominal segment. Six other pairs of abdominal appendages are present in the embryo scorpion, but they abort.

The respiratory organs consist of four pairs of "lung-books," "pulmonary sacs," or "chambered tracheæ," lying in the broad part of the abdomen, and opening by slit-like stigmata on the third to the sixth abdominal segments. Each is like a little purse with many compartments. Air fills the cavity, but there is blood round about. They are believed

by some to be modified tracheæ, reduced to chambers with very much plaited walls, but Ray Lankester regards them as invaginated modifications of gill-books such as *Limulus* possesses.

The nervous system conforms to the Arthropod type, and consists of a dorsal supra-œsophageal ganglionic mass or brain, a ventral chain of seven paired ganglia, and the usual œsophageal ring uniting the most anterior pair with the brain above. The sense-organs include a pair of eyes near the middle of the cephalothoracic shield, with others on the anterior margin. Those in both positions are simple, *i.e.*, with one lens each (monomeniscous); the central eyes have a vitreous and a retinal layer (diplostichous); those on the margin have only one layer (monostichous).

Scorpions suck the blood of living animals (insects, etc.), which they may kill with their sting or seize with their pedipalps, and hold close to the mouth by their cheliceræ. The pharynx is a suction pump, the alimentary canal is unusually narrow. Several outgrowths from the mid-gut form a digestive gland. A pair of excretory Malpighian tubes grow out from the hind-gut.

The body-cavity is for the most part filled up with organs, muscles, and connective tissue. A paired ductless coxal gland occurs in relation to the base of the last thoracic legs.

The blood contains the common respiratory pigment hæmocyanin and amœboid corpuscles. An eight-chambered dorsal heart, lying within a pericardium, gives off an anterior aorta supplying head and limbs and curving backwards from the head to follow the ventral nerve-cord; and there is also a posterior aorta, besides some lateral arteries from the heart chambers. From capillaries the blood is gathered into a ventral venous sinus, is purified by the chambered tracheæ, and returns by venous channels to the pericardium and thence into the heart.

The sexes are separate; the testes consist of two, the single ovary of three, longitudinal tubes united by cross bridges; the male or female ducts open at a single aperture beneath the operculum on the first abdominal segment; there is a copulatory organ at the end of the vas deferens. The ovum undergoes total segmentation; the young are developed

within the mother and are born "viviparously." After birth they adhere for a while to the body of their mother.

The race of scorpions is of very ancient origin, for one has been found in Silurian strata, and others nearly resembling those now alive are found in the Carboniferous.

Examples.—*Scorpio.*
Euscorpius.
Buthus.
Androctonus.

Order 2. SOLPUGIDÆ or SOLIFUGÆ, *e.g.*, *Galeodes* or *Solpuga.*

Active, pugnacious, venomous, nocturnal little animals, found in the warmer parts of the earth, *e.g.*, in the United States. The head is separate from the thorax. The thorax has three segments, the abdomen nine or ten. The chelicerae are chelate, the pedipalps like long legs. The respiration is by means of tubular tracheæ. The segmentation of the thorax is very remarkable.

Order 3. PSEUDOSCORPIONIDÆ. "Book-Scorpions," *e.g.*, *Chelifer*, *Chernes*, *Obisium.*

Very small animals, found especially in warm climates, under bark, in books, under the wing-covers of insects, etc. They are like miniature scorpions, but without the long tail and sting. Their food probably consists of the juices of insects; the chelicerae are minute suckers, the pedipalps like those of scorpions. The abdomen is broad, with eleven segments. They breathe by tubular tracheæ, and have spinning glands.

Order 4. PEDIPALPI. "Whip-Scorpions," *e.g.*, *Thelyphonus*, *Phrynus.*

Small animals, found in warm countries. The abdomen is depressed, and consists of eleven or twelve segments. The chelicerae are simply clawed, but are poisonous; the pedipalps are simply clawed or else truly chelate. The first pair of limbs are very thin. They breathe by two pairs of chambered tracheæ. In *Thelyphonus* there is a long terminal whip.

Order 5. PHALANGIDÆ. "Harvest-men," *e.g.*, *Phalangium*, *Gonyleptes.*

The small "harvest-men" are noted for their extremely long legs, by which they stalk slowly along avoiding the glare of the day. They are sometimes called daddy-long legs, but we reserve that name for the crane-fly (*Tipula oleracea*). Nor are they to be confused with the troublesome "harvest-bugs" (*Trombidium holosericeum*), for these are very minute red mites (Acarina). The harvest-men are not troublesome to us, but feed on small insects.

The abdomen is broad, six-segmented. The cheliceræ are chelate, the pedipalps like legs. The legs are extremely long. Respiration is effected by tubular tracheæ.

To avoid multiplying orders (there are enough as it is), I include here the Cyphophthalmidæ, which have cheliceræ and pedipalps similar to the above, but an eight-segmented abdomen, and the habits of book-scorpions; *e.g.*, *Cyphophthalmus* and *Gibbocellum*.

Order 6. ARANEIDÆ. Spiders.

Spiders are found almost everywhere upon the earth, and some are at home in fresh water. Most of them live on the juices of insects, and many form webs in which these are snared. The courtship of spiders is often a very complex affair, and in some cases the males run a great risk of being devoured by their larger and stronger mates. Before stating the peculiarities of structure, we shall briefly consider the spinning and the courtship of spiders.

Spinning.—At the end of the abdomen there are usually three pairs of spinnerets. Each is a perforated papilla, comparable to the rose of a watering-can, and is connected internally with the tubes of spinning glands. When these glands are compressed a viscid material oozes out from the spinnerets or from some of them. The extremely thin filaments from the tubes of each spinneret unite into a thread, and the thread of one spinneret is often combined with that from the others. In this way a compound thread of exquisite fineness, though rivalled by a quartz fibre, is produced, but two or four separate threads are often exuded at the same time. Before beginning to "spin," the spider often presses the spinnerets against the surface to which the thread is to adhere, and draws the filaments out by slowly moving away. Often, however, the filaments ooze out quite apart from any attachment. The legs are also much used in extending and guiding the thread, and some spiders have on the hind legs a special comb of stiff hairs.

One of the most important ways in which the secreted threads are used is in forming a web. The common garden-spider (*Epeira*) makes a web which is a beautful work of art, and very effective as a snare for insects. The spider carries a thread across the selected area and fixes it firmly;

another and another is formed all intersecting in one centre; in this way the radiating rays of the web are made. Secondly, it starts from the centre, and moves from ray to to ray in a long close spiral gradually outwards, leaving a strong spiral thread as it goes. Thirdly, the spider moves in a closer spiral from the circumference inwards, biting away the former spiral, replacing it by another, which is viscid and adhesive. It is to this that the web chiefly owes its power of catching insects which light there. There is usually a special thread running to the adjacent hole or nest, and the entire fabric is wonderfully sensitive, for the spider feels rather than sees when a victim is caught. Indeed a little piece of cork, dexterously twirled on the end of a thin wire, and made to strike the strands of the web, will often deceive the cunning spider.

The spun threads are used in many other ways. They line the nest, and form cocoons for the eggs. They often trail behind the spiders as they creep, for instance over a ploughed field. They greatly assist locomotion, and are used in wonderful feats of climbing. Small and young spiders often stand on their head on the top of a fence, secrete a parachute of threads, and allow themselves to be borne by the wind.

Courtship.—The males are usually much smaller than the females. It is calculated that the disproportion is sometimes such as would be observed if a man 6 feet high and 150 pounds in weight were to marry a giantess of 75–90 feet high, 200,000 pounds in weight. I believe that the smallness of the males is in great part due to the fact that they are males; others explain it by saying that the smaller the males are the less likely they are to be caught by their frequently ferocious mates. It is difficult, however, to understand how this characteristic smallness, though perhaps advantageous and likely to be favoured by natural selection, could be entailed on the male offspring only. But this difficulty in regard to inheritance is one which besets many similar applications of the theory of natural selection.

The males are often more brilliantly coloured than the females, mainly, I believe, because they are males, though what the physiological connection between the male constitution and bright colours in this case is we cannot tell till

the nature of the pigments is known. Wallace has spoken of the frequent brilliancy of males as due to their greater vitality, and refers the relative plainness common in females to their greater need for protection. Darwin referred the greater decorativeness of males to the fact that those which varied in this direction found favour in the eyes of their mates, were consequently more successful in reproduction, and thus tended to entail brilliancy on their male successors. But we naturally ask how the brilliancy began, and how its enhancement is transmitted to males alone. In the "*Evolution of Sex*," Professor Geddes and I have recognised that sexual selection may help to establish the brilliancy of males, and that natural selection may help to keep the females plain, but have also sought to associate decorative and other differences between the sexes with the more fundamental qualities of maleness and femaleness.

I have introduced this subject here, not only because it affords a pleasant interlude in our systematic survey, and because it serves to illustrate the problems of evolution, but also because natural history has lately been enriched by a valuable series of observations on sexual selection in spiders.

Two American observers, Mr. and Mrs. Peckham, have made a series of studies on the courtship of spiders more careful than any others of the kind. (Occasional Papers of the Natural History Society of Wisconsin. Milwaukee, 1889.)

They find "no evidence that the male spiders possess greater vital activity; on the contrary, it is the female that is the more active and pugnacious of the two." They find "no relation, in either sex, between development of colour and activity; the Lycosidæ, which are among the most active of all spiders, having the least colour development, while the sedentary orb-weavers show the most brilliant hues." "In the numerous cases where the male differed from the female by brighter colours and ornamental appendages, these adornments were not only so placed as to be in full view of the female during courtship, but the attitudes and antics of the male spider at that time were actually such as to display them to the fullest extent possible." "The males were much more quarrelsome in the presence of the females, and to a great extent

lost their tendency to fight when the mating season was over."

The courtship is prolonged and elaborate, the females are not only coy but often savage. The male's love-making is often cut short by his death at the hands or cheliceræ of his desired mate. Of course we must be careful not to exaggerate the subtlety of the mental processes involved in the courtship of animals; we must also beware of regarding it too crudely. I do not think that any one who reads the romantic account which the Peckhams have given of the spiders which they watched so patiently will doubt that sexual selection exists in a marked degree among spiders.

"The fact that in Attidæ the males vie with each other in making an elaborate display, not only of their grace and agility, but also of their beauty, before the females; and that the females, after attentively watching the dances and tournaments which have been executed for their gratification, select for their mates the males which they find most pleasing, points strongly to the conclusion that the great differences in colour and in ornament between the males and females of these spiders are the result of sexual selection."

It is still, however, quite possible that the colouring and decorations may have arisen as natural outcrops of the male constitution, the characteristics of which are by no means limited to greater vitality or activity.

Structural Characters of Spiders.

The form of the body is well-known,—an unsegmented cephalothorax, an unsegmented oval abdomen, and a narrow isthmus between them.

The chitinous cuticle is often moulted as the spider grows. The abdomen is soft.

Colouring is common, often harmonising with the surroundings, often a sexual characteristic.

There are six pairs of appendages—

(1) The clawed cheliceræ or falces, in which the last joint bends against the second last, contain poison-glands.

(2) The leg-like pedipalps, the terminal joint of which is modified in the male for copulation.

(3–6) Four pairs of walking-legs. The front pair are much used as feelers. The embryo has other four pairs of abdominal legs which abort.

In front of the anus there are 4–6 spinnerets, from which the silk secretion oozes.

The nervous system conforms to the usual type, but there is great centralisation, for there is a single ganglionic mass in the thorax from which nerves proceed to the organs.

There are two or three rows of eyes on the cephalothorax dorsally and anteriorly; they are like the central eyes of the scorpion. "Auditory hairs" are found on the pedipalps and legs, and a sensory organ, probably olfactory or gustatory, occurs on the basal joint of the pedipalps. It is supposed that some spiders see fairly well; many trust more to touch and hearing.

The spider feeds on the juices of insects, and behind the gullet there is a powerfully suctorial region. Five pairs of outgrowths from the mid-gut extend into the bases of the legs. There are also tubular digestive outgrowths, and two excretory Malpighian tubes grow out from the hind-gut.

Body-cavity, entosternite, and coxal glands generally resemble those of the scorpion.

The three-chambered heart, with three pairs of valved openings, lies dorsally in the abdominal region, within a pericardium in some forms at least. As regards the blood and its circulation there is no great difference between spiders and scorpions.

Respiration is effected by four chambered tracheæ or "pulmonary sacs" in one set (Tetrapneumones, *Mygale*, etc.), by two chambered tracheæ plus tubular tracheæ in the great majority (Dipneumones). In every case the openings are abdominal and ventral, but the two chambered tracheæ present in most open in the front of the abdomen, the tubular tracheæ posteriorly near the spinnerets.

The males are smaller, and often more brightly coloured than the females. The reproductive organs are usually paired. Two vasa deferentia open beside the apertures of the pulmonary sacs; the oviducts unite and open in the same position. Most females have receptacula seminis independent of, and opening in front of the genital aperture.

The spermatozoa are transferred to the last joint of the male's pedipalps, which are thrust into the receptacle or into the vagina of the female.

The segmentation of the ovum is centrolecithal, *i.e.*, peripheral. A cocoon is usually formed around the eggs, this is often carefully hidden or carried about by the female. There is great maternal solicitude, though there is little conjugal affection.

Fossil forms are often found imprisoned in amber.

Examples—

1. Tetrapneumones, *e.g.*, *Mygale*, a large lurking spider which has been known to kill small birds, but usually eats insects. *Atypus*, *Cteniza*, etc., make neat trap-door nests.

2. Dipneumones, including web-spinners, *e.g.*, *Epeira*; wolf-spiders, *e.g.*, *Lycosa*, *Tarantula*, the latter with poisonous qualities which have been much exaggerated; jumping-spiders—the family Attidæ, *e.g.*, *Attus*, *Salticus*. The common house-spider is *Tegenaria domestica*. *Argyroneta aquatica* fills a sub-aquatic silken nest with air-bubbles caught at the surface.

Order 7. ACARINA. Mites and Ticks, *e.g.*, Cheese-mite (*Tyroglyphus*).

Mites are minute Arachnoids inclined to parasitism. They occur in the earth or in water, salt and fresh, or on animals and plants. They feed on the organisms they infest or upon organic débris.

The abdomen is fused with the cephalothorax, both are unsegmented. According to the mode of life, the mouth-parts are adapted for biting or for piercing and sucking. Respiration may be simply through the skin (it is a puzzle how some of the parasitic mites manage to breathe at all); in the majority there are tracheæ with two stigmata. Many of the young have only three pairs of legs when hatched, but soon gain another pair. When some mites are starved or desiccated, and to some extent die, certain cells in the body unite within a cyst, and are able in favourable conditions to regrow the animal.

Examples—

(*a*) Without tracheæ. Cheese-mite (*Tyroglyphus*). Itch-mite (*Sarcoptes scabiei*), causing a loathsome disease. *S. canis* causes "mange" in dogs. Follicle-mite (*Demodex folliculorum*), common in the hair-follicles and sebaceous glands of man. Gall-mites (*Phytoptus*), on plants.

(*b*) With tracheæ. Harvest-mites (*Trombidium*), minute parasites often troublesome in summer. Water-mites (*Atax*; *Hydrachna*). *Atax ypsilophorus* occurs on the gills of the fresh-water mussel. Beetle-mites (*Gamasus*), often found on carrion beetles. Ticks (*Ixodes*), on dogs, cattle, etc.

Order 8. LINGUATULIDA. *Pentastomum tænioides.*

This strange animal is parasitic in the nasal and frontal cavities of the dog and wolf. It is worm-like in form, externally ringed, without any oral appendages, but with two pairs of moveable hooks near the mouth. There are no sense-organs nor tracheæ. The sexes are separate, the males smaller than the females.

Embryos within egg-cases pass from the nostrils of the dog. If they happen to be swallowed by a rabbit or a hare, or it may be some other mammal, the embryos hatch in the gut and penetrate to liver or lung. There they encyst, moult, and undergo metamorphosis. The final larval form is not so unlike an Arachnoid as the adult is. Liberated from its encystment, it moves about within its host, but will not become adult or sexual unless its host be eaten by dog or wolf. There are a few other species occurring in Reptiles, Apes, and even man, but their history is not adequately known.

Order 9. TARDIGRADA. Water-Bears or Sloth-animalcules, *e.g.*, *Macrobiotus.*

Microscopic animals, sometimes found about the damp moss of swamps or even in the roof-gutters of houses. The body is somewhat worm-like, with four pairs of clawed limbs like little stumps, with mouth-parts resembling those of some mites, and adapted for piercing and sucking. There is no abdomen. There is a food-canal, a brain and a ventral chain of four ganglia, sometimes even a pair of simple eyes, but no respiratory or vascular organs. They are the only hermaphrodite Arachnoids, if they are Arachnoids. The eggs, which are enveloped in the cast skin of the parent, undergo total segmentation, but little is known in regard to their development.

The water-bears are said to have great powers of successfully resisting desiccation, but perhaps it is the enclosed eggs which do so, developing rapidly when favourable conditions return.

Some authorities dignify (8) and (9) as classes; for reasons of practical expediency I continue to call them orders.

BRANCHIATE ARACHNOIDEA (Pœcilopoda).

Order 10. XIPHOSURA. King-Crab or Horse-shoe Crab (*Limulus*).

The King-crab or Horse-shoe crab lives on the muddy or sandy shore of the sheltered bays and estuaries of N. America,

from Maine to Florida and the West Indies, and also on the Molucca Islands, etc., in the far East. The body consists of a vaulted cephalothorax shaped like a horse-shoe, and an almost hexagonal abdomen ending in a long spine. Burrowing in the sand, *Limulus* arches its body at the joint between cephalothorax and abdomen, and pushes forward with legs and spine. It may also walk about under water, and even rise a little from the bottom. It is a hardy animal, able to survive exposure on the shore or even some freshening of the water. Its food consists of worms and small animals found in the sand. There are two or three different species (*L. polyphemus* from N. America, *L. moluccanus* from the East).

The King-crab is interesting in its structure and habits, and also because it is the only living representative of an old race. Since Ray Lankester published in 1881 a famous paper entitled "Limulus an Arachnid," it has been generally, though not unanimously recognised, that the King-crab's relationships among modern animals are with Arachnoidea, not with Crustacea.

The horse-shoe-shaped hard, chitinous cephalothoracic shield is vaulted, but the internal cavity is much smaller than one would at first sight suppose; the abdomen is all of one piece, also covered by a shield; the long sharp spine is (like the scorpion's sting) a post-anal telson.

On the concave under surface of the cephalothorax, there are six (or seven) pairs of limbs, as in spiders and scorpions :—

(1) A little pair of cheliceræ in front of and bent towards the mouth. (They are chelate in the female, simply clawed in the male.)

(2–6) Five pairs of walking-legs, the bases of which surround the mouth and help in mastication. (The last of these ends in two flat spines, which, along with others a little higher up, help the animal in walking on soft sand. The other appendages are usually chelate.)

(7) Then follows on the abdomen a double "operculum" overlapping the rest. (Some refer this operculum to the cephalothorax.)

(8–12) Under the operculum lie five pairs of flat plates bearing remarkable respiratory organs ("gill-books"). (These appendages are said by some to show hints of the exopodite and endopodite structure characteristic of Crustaceans.)

As in the scorpion, there is an internal skeletal structure, or entosternite serving for the attachment of muscles.

The Nervous System.—The supra-œsophageal brain gives off nerves to the eyes. United to the brain are two ganglionated and transversely connected cords forming an oval in the cephalothorax, giving off nerves to the limbs, and continued into a ganglionated abdominal cord.

There are two "compound" eyes lying towards the sides of the cephalothoracic shield, and in front of these two more median simple eyes. The compound eyes are covered by a layer of chitin continuous with that of the shield, and the various eye-elements are so remarkably distinct from one another, that the eye might be called a group of simple eyes.

The Food-Canal.—Worms and other animals seized by some of the pincers, are partly masticated by the bases of the five posterior cephalothoracic legs. From the mouth the fore-gut bends upwards and forwards into a crop with internally folded chitinous walls. The mid-gut extends along the cephalothorax and abdomen, and in the former bears two pairs of large hepato-pancreatic digestive outgrowths. The hind-gut is short and ends in front of the base of the spine.

Two reddish coxal glands lie in the cephalothorax, and open in young forms at the bases of the fifth appendages.

The Vascular System.—The heart lies within a pericardium and is eight-chambered, with eight pairs of valved ostia. Hæmocyanin is present as usual as the respiratory pigment of the blood. From an anterior aorta like that of the scorpion, two vessels are given off which bend backward ventrally, ensheathing the œsophageal nerve-collar and its continuations. There are also four pairs of lateral vessels from the heart which unite in a longitudinal trunk on each side. From capillaries, the blood is gathered into a ventral venous sinus, whence it passes to the respiratory organs, and thence to the pericardium and heart.

The respiratory organs are borne by the last five appendages. They look like much plaited gills. Their leaf-like folds are externally washed by the water, within them the blood flows. According to Ray Lankester, they are comparable structurally to the pulmonary sacs of the scorpion.

The Reproductive System.—The males are smaller than the females. The testes are very diffuse, the two vasa deferentia open on the internal surface of the operculum, and the spermatozoa, which are vibratile, seem to be shed into the water. The ovaries form two much branched but connected sacs; the oviducts are separate, and enlarge before they open beneath the operculum.

Spawning occurs in the spring and summer months, the favourite time being at the full moon, when the tides run unusually high. The ova and spermatozoa are deposited in hollows near high-water mark. Some of the early stages of development, still imperfectly known, present considerable resemblance to corresponding stages in the scorpion. In the larvæ, both cephalothorax and abdomen show signs of segmentation, but these disappear. The spine is represented only by a very short plate, and the larva presents a striking superficial resemblance to a Trilobite.

It seems likely that Limulus is linked to the extinct Eurypterids by some fossil forms known as Hemiaspidæ, *e.g.*, *Hemiaspis*, *Belinurus*, *Bunodes*.

Order 11. EURYPTERINA (= Merostomata), *e.g.*, *Eurypterus*, *Pterygotus*.

Extinct forms found from Upper Silurian to Carboniferous strata. The cephalothorax (?) bore five to six pairs of appendages, two lateral compound eyes, and two median ocelli. The abdomen (?) consisted of twelve segments without appendages. At the end of the body was a spine-like or rudder-like telson. Some of them measured many feet in length.

Some incline to keep the Eurypterids near Crustaceans, but the favourite opinion seems to be that which links them through *Limulus* to Arachnoids.

Order 12. TRILOBITA. Trilobites, *e.g.*, *Calymene*, *Phacops*, *Asaphus*, *Agnostus*.

Extinct forms chiefly found in Cambrian and Silurian strata, but extending to the Carboniferous. There was a cephalothorax with four pairs of limbs around the mouth, and sometimes bearing dorsal compound eyes. The abdomen was divided into an anterior segmented and a posterior unsegmented region, both with limbs.

The body was externally divided by a median longitudinal ridge into three longitudinal portions. Trilobites are often found rolled up in a way that reminds one of some wood-lice. So abundant are they in some rocks, that even their development has been studied with some success.

The limbs appear to be liker those of Crustaceans than of Arachnoids, but the present balance of opinion seems to be in favour of placing them nearer Arachnoids. It is possible that they are offshoots from a stock ancestral to both.

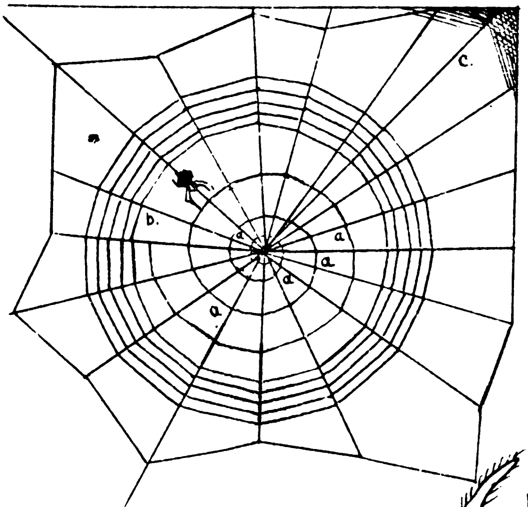
Appendix to Arachnoidea:—

PANTOPODA or PYCNOGONIDÆ.

These are marine Arthropods, sometimes called sea-spiders. Their affinities are uncertain, but perhaps they may be ranked between Crustaceans and Arachnoids. Many climb about seaweeds and hydroids near the shore, but some live at great depths. The body consists of an anterior proboscis, a cephalothoracic region with three fused and three free segments, and an unsegmented rudimentary abdomen. In most there are seven pairs of appendages, into five of which outgrowths of the mid-gut extend. The sexes are separate, and the males usually carry the eggs attached to the third pair of appendages. The larvæ are at first unsegmented, with three pairs of appendages.

Examples :—*Pycnogonum*, *Nymphon*, *Ammothea*.

Arachnida.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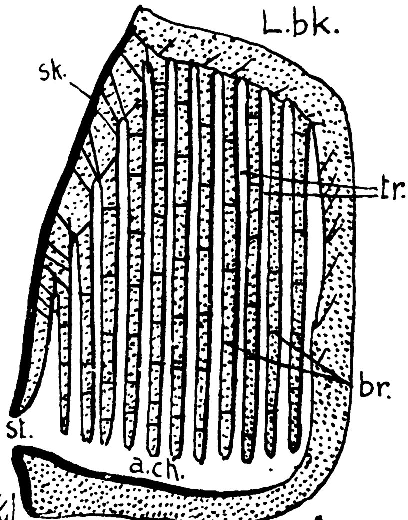
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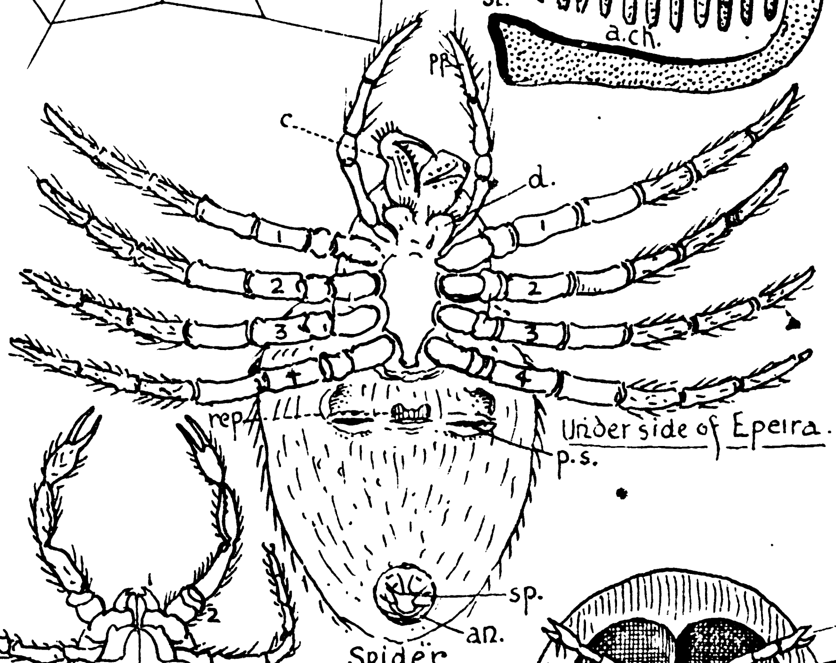
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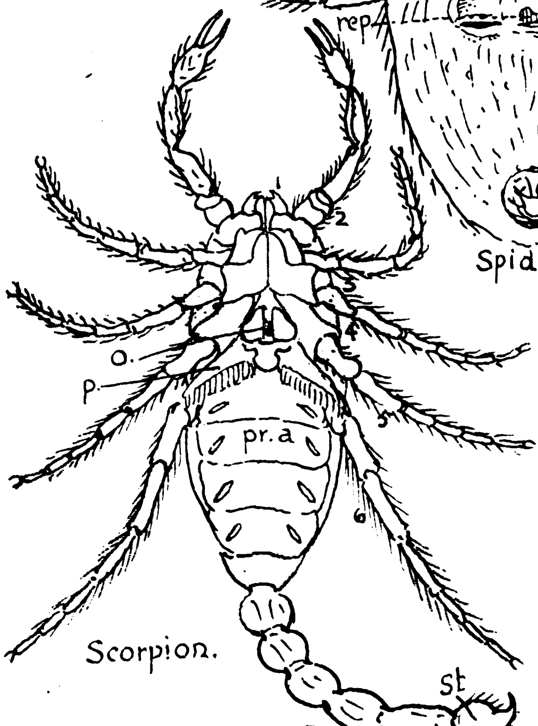
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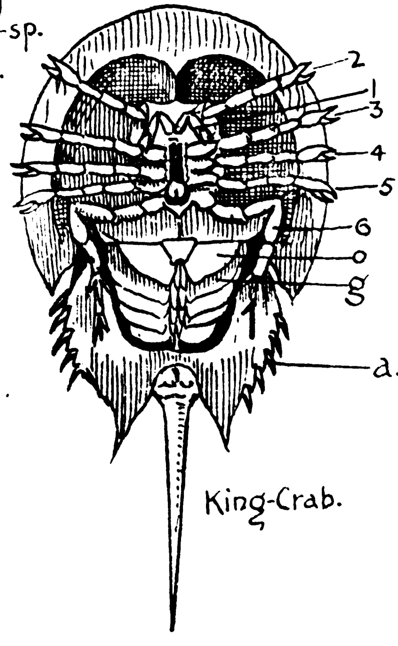
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DIAGRAM XIV.

ARACHNOIDEA.

The figure of a scorpion shows the under surface :—(1) the chelicerae, (2) the pedipalps, (3–6) the walking-legs, *o.* the operculum, *p.* the pectines, *pr. a.* the præ-abdomen, with four pairs of respiratory apertures, *p. a.* the post-abdomen, with a terminal sting (*st.*).

The figure of the king-crab (after Packard) also shows the under surface :—(1) the appendages in front of the mouth, (2–6) the walking-legs, *o.* the operculum, *a.* the abdomen, *g.* the appendages with gill-books.

In the centre of the diagram, the under side of the garden spider (*Epeira*) is shown (after Vogt and Yung) :—*c.* the chelicerae, *pp.* the palps, *d.* parts often distinguished as jaws, 1–4 the walking-legs, *rep.* and *p. s.* the openings of the reproductive ducts and pulmonary sacs, *an.* the anus, *sp.* the opening of the spinnerets.

In the right upper corner is a section of a chambered trachea, pulmonary sac, or lung-book (*L. bk.*) (from Lang, after Macleod). The outer skin (*sk.*), the aperture or stigma (*st.*), the air-chamber (*a. ch.*), the tracheal cavities (*tr.*), the bridges (*br.*) uniting the walls of adjacent tracheæ, are marked.

To the left is the web of a garden spider, showing (*a*) the first spiral, (*b*) the second spiral, (*c*) the radial filaments. (From the *Standard Natural History.*)

CHAPTER XIV.

MOLLUSCS.

The MOLLUSCA include three large classes :—

Lamellibranchiata or Bivalves.	Gasteropoda or Snails.	Cephalopoda or Cuttlefishes.

[A separate small class includes the Elephant's Tooth Shells (*Dentalium*), and some authorities admit some other small classes.]

General Characteristics of Mollusca.

Most Molluscs live in the sea, from the shore to the great depths, but there are many fresh-water Gasteropods and bivalves, and the terrestrial snails and slugs are legion.

The bivalves feed on microscopic animals and organic débris ; the Gasteropods are carnivorous or vegetarian ; the Cephalopods are voracious flesh-eaters. The members of the last two classes have a rasping ribbon (radula) in their mouths.

In contrast to the ringed Arthropods and Annelids, the Molluscs are unsegmented and without serial appendages.

The bilateral symmetry of the larva is usually retained in the sluggish bivalves and in free-swimmers, *e.g.*, cuttlefishes, but most Gasteropods are markedly lop-sided.

A single or double fold of skin, called the mantle, lines

and makes the calcareous shell which in single or double form is characteristic of most Molluscs, except the modern cuttlefishes and the land and sea slugs.

A muscular protrusion of the ventral surface forms the "foot," by aid of which most Molluscs move.

The nervous system includes three chief pairs of nerve-centres, the cerebral, the pleural, and the pedal ganglia, often with accessory viscerals, etc. In the bivalves where the head-region is undeveloped the ganglia are far apart; in snails and cuttlefishes, they are concentrated in the head and form a nervous mass around the gullet.

The alimentary canal and its associated digestive gland, often seem as if they were too big for the body; in bivalves the gut tends to be displaced ventrally and coils about in the foot, in the others it tends to be displaced dorsally, often protruding on the back as a visceral hump.

Two larval stages are very common—a trochosphere resembling that of some worms, and thereafter a more characteristic "veliger."

While there are many active swimmers among Molluscs, the average habit is sluggish.

For a diagrammatic summary of the chief anatomical characters, see Ray Lankester's Schematic Archi-Mollusc, a reconstruction of a possible ancestor. A simplified copy of this is given in Diagram I.

General Classification.—The frequent occurrence of a trochosphere larva, the characters of the very simplest Gasteropods, and other facts support the readily-made suggestion, that in the ages of which we have no geological record, Molluscs originated from some worm-type or other. But this is very vague.

It is certain, however, that the great mollusc branch must have divided at a very early stage into two. One branch, bent downwards, bears those forms which live sluggishly and have undeveloped heads—the bivalves or Lamellibranchs. The other branch bears more active forms, with well-developed heads and raspers in their mouths, the Gasteropods or "snails," and the Cephalopods or "cuttles." The simplest known Molluscs are ranked with Gasteropods, but it is convenient to describe Lamellibranchs first.

Mollusca.

Branch GLOSSOPHORA (Syn. Odontophora).	Branch LIPOCEPHALA (Syn. Acephala).
Class Cephalopoda—*Nautilus* and cuttle-fishes.	
Class Gasteropoda. { Asymmetrical Anisopleura, snails, whelks, etc. More primitive, bilaterally symmetrical forms—Isopleura, *e.g.*, *Chiton*.	Class Lamellibranchiata (Syn. Pelecypoda, Conchifera or Bivalves (cockle and mussel, clam and oyster).

Unknown Ancestors.

N.B.—The class Gasteropoda is somewhat heterogeneous, especially if it be made to include the pelagic Pteropods. In the mean time, I have left out the small class of Scaphopoda, but it may be inserted between Gasteropods and Cephalopods.

General Notes on Molluscs.—The three great classes of Molluscs—bivalves, snails, and cuttles—differ so much, that it would be wearisome to discuss them together. A few general notes, however, may find place here.

As the word *mollusca* is but a Latinised form of the Greek *malakia*, which means soft, it is necessary to explain that Aristotle applied the title to the practically shell-less cuttle-fishes, and that Linnæus used it to include Zoophytes, Annelids, Echinoderms, and what we call naked molluscs. Our shelled molluscs were called Testacea. Gradually, however, the word "mollusc" prevailed, and of course oysters and whelks are soft enough apart from their shells. The technical history of "mollusca" well illustrates the progress of classification, for within the last sixty years Cuvier's Cirrhopoda (barnacles and acorn-shells) have been referred to their proper place among Crustaceans, his Nuda (Tunicates) have been raised to the rank of incipient Vertebrates, the lamp-shells or Brachiopoda have been dismissed from among Molluscs, and thrown along with Polyzoa into the company of diverse "worms," or conveniently labelled "incertæ sedis." These changes have made the Mollusca into a well-defined series.

The shell is a very characteristic molluscan structure, and till we understand it better we must confess ourselves very ignorant of the nature of Molluscs. But in spite of all the years of conchology, we cannot answer the fundamental questions about shell-making. Mollusc shells are very

beautiful things alike in form and colour, they grow larger by month and year, and mark their progress by rings of growth and changing tints of colour, they afford their bearers efficient protection which the hermit-crabs who steal whelk and buckie shells evidently appreciate. More precise observation shows us that the shell consists in great part of carbonate of lime; that it has a thin outer "horny" layer, a thick median "prismatic" stratum of lime, and an internal mother-of-pearl layer with the usual iridescence produced by fine markings and repeated, according to Brewster's famous experiments, on its impress on a piece of wax. On the dorsal surface of almost every mollusc embryo, there is a little shell-sac in which an embryonic shell is begun; the adult shell, however, begins on a separate area of the skin, and it is always lined and increased by the mantle. If the increase of the shell be carefully watched on young molluscs, or if chemical analysis be made, it becomes plain that the shell is no mere deposition of carbonate of lime. Like other cuticular products, it has an organic basis (called conchiolin), along with which, in a manner that we do not clearly understand, the lime is associated.

Mr. Irvine's experiments at Granton Marine Station suggest that the lime salt originally absorbed is not the carbonate (of which there is a scant supply in sea-water), but the sulphate (which is abundant), and that the internal transformation from sulphate to carbonate is perhaps associated with the diffuse decomposition of nitrogenous waste-products. Thus carbonate of ammonia, which seems to occur abundantly in the mantle of perfectly fresh mussels, would, with calcium sulphate, yield carbonate of lime and ammonium sulphate. I do not suppose that shell-making is expressible in a chemical equation of this simplicity, but it is time that we ceased to think that Molluscs simply absorb carbonate of lime from the sea-water, and sweat it out on their skins. It is reasonable to inquire how far shell-making may express a primitive mode of excretion to which a secondary significance has come to be attached, and in what way carbonate of lime shells are associated with preponderant sluggishness of habit. The thickness of the shell seems often to bear some relation to the external and internal activities of the mollusc, for it is thin in the active scallop

(*Pecten*) and *Lima*, thick in the passive oyster and *Tridacna*, slight or absent in the pelagic Pteropods ("sea-butterflies"), and in the more or less active cuttlefishes, but heavy in most of the slowly creeping littoral forms. But that this is only one condition of shell-development is evident in many ways, —for instance when we compare land-snails with slugs; for the latter, though not more active than the former, are practically shell-less.

In their life-history most Molluscs pass through two larval stages. The first of these is a pear-shaped or barrel-shaped form, with a curved gut, and with a ring of cilia in front of the mouth. It is a trochosphere, such as that occurring in the development of many "worms." So far there is nothing characteristic.

Soon, however, the trochosphere grows into a yet more efficiently locomotor form—the veliger. Its head bears a ciliated area or "velum," often produced into retractile lobes; its body already shows the beginning of "foot" and mantle; on the dorsal surface lies the little embryonic shell-gland.

But although trochosphere and veliger occur in the development of most forms, they do not in any of the three types which we shall afterwards describe,—not in *Anodonta* partly because it is a fresh-water animal, with a peculiarly adhesive larva of its own, not in *Helix* partly because it is terrestrial, and not in *Sepia* partly because the eggs are rich in yolk.

Finally, be it noted that the hard shells of extinct Molluscs are naturally well preserved in the rocks, and that long series of fossil forms have been traced with much success.

Class LAMELLIBRANCHIATA—Bivalves.

(Syn. Acephala, Conchifera, Pelecypoda, Lipocephala, etc.)
e.g., Cockles, Mussels, Clams and Oysters.

General Characters of Bivalves.

The great majority live in the sea, but some have become accustomed to fresh water, by slowly spreading from estuaries to rivers, or by the gradual alteration of inland seas. In habit they are very sluggish, and often quite sedentary,

active forms like *Pecten* and *Lima* being exceptional. In the most sluggish, such as oysters, the foot is degenerate. They feed on microscopic plants and animals and on particles of organic débris, which are wafted to the mouth by the lashing cilia on the gills. The mouth is without any prehensile or rasping structures. Bilateral symmetry is retained. Thus there are two mantle folds, two shell-valves united dorsally by an elastic ligament, two auricles to the heart; and the plate-like gills (ctenidia), formed from the growing together of gill-filaments,—the kidneys (nephridia), the digestive gland, and the reproductive organs are all paired. But the head region remains undeveloped. There are no head-eyes. The nervous system usually consists of three pairs of ganglia—(*a*) in the head (cerebro-pleurals), (*b*) in the foot (pedals), and (*c*) at the posterior end of the body (viscerals). The sexes are usually separate, but there are many bisexual forms. The reproductive organs (ovaries and testes) are simple, without accessory structures.

Further Remarks on Bivalves in General.—We may associate the sluggish habits and sedentary life of bivalves, (1) with the undeveloped state of the head-region, (2) with the largeness of the plate-like gills which waft food-particles to the mouth, and (3) with the thick limy shells. We may reasonably associate these and other facts of structure (*e.g.*, the absence of head-eyes, biting or rasping organs) with the conditions of life, without being able to say very precisely what the relation is. It seems to me most likely that sluggish habits have cumulative and manifold results in the course of generations, and that the structural changes produced by surroundings, or by use and disuse of parts, have constitutional consequences which may affect the germ-cells, that is to say, the offspring. To others the adaptations seem to be most readily explained as the result of the natural selection of fortuitous or indefinite variations. In thinking about the sluggishness of most bivalves, we must not of course forget that the larval trochospheres and veligers are very active, perhaps almost too active, young creatures.

Habit.—Most bivalves, as every one knows, live in the sea, and extend from the sand of the shore to great depths. They occur in all parts of the world, though only a few forms like the edible mussel (*Mytilus edulis*) can be called cosmopolitan. Some, such as oysters, can be accustomed to brackish water. The fresh-water forms may have found their habitat in two ways—(*a*) a few may have crept slowly up from estuary to river, from river to lake; *Dreissena polymorpha* has been carried on the bottom of ships from the Black Sea to the rivers and canals of Northern Europe; and it is likely that aquatic birds have assisted in distributing little bivalves like *Cyclas*; (*b*) on the other hand, it is more likely that the fresh-water mussels (*Unio*, *Anodonta*, etc.),

are relics of a fauna which inhabited former inland seas, of which some lakes are the freshened residues.

Between the active *Lima* and *Pecten*, which swim by moving their shell-valves and mantle-flaps, and the entirely quiescent oyster, which has virtually no foot, there are many degrees of passivity, but most incline towards the oyster's habit. Of course, there is much internal activity, especially of ciliated cells, even in the most obviously sluggish. The cockle (*Cardium*) uses its bent foot to take small jumps on the sand; the razor-fish (*Solen*) not only bores in the sand, but may swim backwards by squirting out water from within the mantle-cavity; many (*e.g.*, *Teredo*, *Pholas*, *Lithodomus*, *Xylophaga*), bore holes in stone or wood, but we do not certainly know how; in the great majority the foot is used for slow creeping movement.

The food consists of Diatoms and other Algæ, Infusorians and other Protozoa, minute Crustaceans and organic particles, which the ciliary action of the gills carries from the posterior end of the shell to the mouth. The bivalves are themselves eaten by worms, starfishes, gasteropods, fishes, birds, and even mammals.

Life-History.—We do not know very much about the development of bivalves. In almost all the known cases, the eggs are fertilised in the mantle-cavity by spermatozoa drawn in with the water. The segmentation, influenced by the presence of some yolk, is unequal. A gastrula is formed by invagination or overgrowth. In rare cases (*Galeomma*, *Kellia*) the larvæ issue as such from the genital apertures, but in most they are sheltered for a while in the mantle-cavity, or gill-cavities (Unionidæ), or in special brood-chambers (*Cyclas* and *Pisidium*). The larva developed from the gastrula is usually a trochosphere and thereafter a veliger, and enjoys a period of free-swimming before settling down. In the fresh-water forms the velum is not developed, and the larva is adapted by attaching threads, or by a grasping shell to resist being swept away by currents. In the fresh-water mussels it becomes for a time parasitic on the gills of a fish.

Past History of Bivalves.—Even in Cambrian rocks, which we may call the second oldest, a few bivalves have been discovered; in the Upper Silurian they become abundant, and never fall off in numbers. About 9000 extinct and 5000 living species were catalogued some years ago, so that we evidently have our full share now. Those with one closing muscle to the shell seem to have appeared after those which have two such muscles. Those which, from the shell-markings, seem to have had an extension of the mantle into a protrusible tube or siphon, were also of later origin. The present fresh-water forms are relatively modern. Of all the fossil forms the most remarkable are large twisted shells called *Hippurites* (Rudistæ), whose remains are often very abundant in deposits of the chalk period.

TYPE OF LAMELLIBRANCHIATA OR BIVALVES: The Fresh-water Mussel (*Anodonta cygnea*).

Mode of Life.—The fresh-water mussel lives in rivers and ponds. It lies with its head end buried in the mud, or

ploughs its way along slowly by means of its wedge-like foot. Its food consists of minute plants and animals, which are wafted in at the upper (or more strictly posterior) end by the currents produced by the ciliated gills. When the mussel is observed during life, it will be seen that small particles in the water move away from and towards the posterior end. Inside the mussel there are usually little water-mites and sometimes other parasitic animals. Crows occasionally catch these mussels, when they have ventured too near the edge of water.

External Appearance.—The bivalve is four to six inches long; its valves are equal and united in a dorsal hinge by an elastic ligament, which is an uncalcified part of the shell; on the ventral surface when the valves gape the foot protrudes; the anterior end is rounded, the posterior end is more pointed, and it is there that the water currents flow in (ventrally) and out (dorsally). The greenish-brown soft ("horny") layer of the shell is often worn away near the dorsal knob or umbo on each side (which is obviously the oldest part), and then displays the median "prismatic" layer of lime. Internally there is a pearly layer. Lines of growth on the shell mark the position of the margin in former years.

The shell is a cuticular structure, *i.e.*, it is made by the epidermis of the mantle. It consists mostly of calcium carbonate plus an organic stuff called conchiolin. The mussels may be found in water which has extremely little carbonate of lime, and the thickness of the shell depends, according to Hatchett Jackson and Rolleston, not upon the amount of lime in the waters, but upon the working of the tissues, modified by surrounding influences whether chemical or non-chemical.

Internal Appearance.—When the right half of the shell is folded back, the anterior and posterior closing muscles being carefully cut close to the gently raised valve, the following parts are readily seen—the mantle folds line the shell and form posteriorly the ventral inhalent and dorsal exhalent lips; internal to the mantle lies on each side a double gill; projecting from between these is the foot, muscular ventrally, softer dorsally; the median dorsal heart cavity is just beneath the hinge ligament; the ventricle shines through its walls, and the dark-coloured kidneys are seen through its

floor. Below the anterior closing (adductor) muscle, the large mouth will be found, bordered beneath by two lip-processes (labial palps) on each side; above the posterior closing muscle the food-canal ends. The whole space between the two mantle flaps is called the mantle cavity, and it is divided by a slight partition at the bases of the gills into a large ventral infra-branchial chamber, and a small dorsal supra-branchial chamber which ends at the exhalent orifice.

On the valve of the shell folded back, are seen a number of marks—the successive attachments of the mantle margin, the insertions of a number of muscles, and perhaps a few small pearls formed by the enclosure of some minute grains of sand in the prismatic layer. The following muscles are inserted on the shell and leave impressions—(*a*) the anterior adductor, (*b*) the posterior adductor, (*c*) the anterior retractor of the foot continuous with (*a*), (*d*) the protractor of the foot a little below (*a*), (*e*) the posterior retractor of the foot continuous with (*b*). As the shell grows the insertion of the muscles and the attachment of the mantle change, and the traces of this shifting are visible.

Skin.—There is much ciliated epithelium about *Anodonta*, on the internal surface of the mantle, on the gills, and on the labial palps; and little pieces cut from an animal incompletely dead (*e.g.*, from the oyster which many of us swallow half alive) have by means of their cilia a slight power of motion. A few investigators maintain that the non-ciliated, but glandular, skin of the foot has pores through which water may enter, but histological and physical facts are decidedly against this conclusion.

Muscular System.—The shell is closed and kept closed by the action of the two adductor muscles. When these are relaxed under nervous control, the elasticity of the hinge ligament opens the valves. A book with an elastic binding stretched when the book is closed by clasps, would in the same way open when unclasped. It is easier for the mussel to open the mouth of its shell than to keep it shut. The "foot" is a muscular protrusion of the ventral surface, and as we have already mentioned, is under the control of three muscles —a retractor and a protractor anteriorly, and a posterior retractor. Its upper portion contains some coils of gut and the reproductive organs; its lower region is very muscular.

The protrusion or extension of this locomotor organ is in part due to an inflow of blood, which is prevented from returning by the contraction of a ring muscle round the veins. In moving, the animal literally ploughs its way along the bottom of the pond or river-pool, and leaves a furrow in its track. The muscle fibres are of the slowly contracting non-striped sort.

Nervous System.—There are three pairs of nerve-centres, for which the following titles are in all probability most accurate :—

(*a*) *Cerebro-pleural ganglia*, lying above the mouth on each side on the tendon of the anterior retractor of the foot, connected to one another by a commissure, connected to the two other pairs of ganglia (*b*) and (*c*) by long paired connectives, and giving off some nerves to mantle, palps, etc.

(*b*) *Pedal ganglia*, lying close together about the middle of the foot, united by connectives to (*a*), giving off nerves to the foot, and having beside them two small ear-sacs each with a calcareous otolith and with a nerve said to be derived from the connective between (*a*) and (*b*).

(*c*) *Visceral ganglia* (also called parieto-splanchnic or osphradial), lying below the posterior adductor, connected to (*a*) by two long connectives, and giving off nerves to mantle, muscles, etc., and to a patch of "smelling cells" at the bases of the gills.

Sense-Organs.—Unlike not a few bivalves which have hundreds of eyes on the mantle margin, *Anodonta* has no trace of any. The ear-sac, originally derived from a skin-pit, is sunk deeply within the foot and is of doubtful use. The "smelling patch" or "*osphradium*" at the base of the gills, has perhaps water-testing qualities. There are also "tactile" cells about the mantle, labial palps, etc.

Alimentary System.—The mouth lies between the anterior adductor and the foot, and beside it lie the ciliated, vascular, and sensitive labial palps, two on each side. A short wide gullet leads into a large stomach surrounded by the paired digestive gland (hepato-pancreas), whose juices are partly analogous with those of the Vertebrate liver and pancreas. Part of the food digested by these juices in the

stomach is compacted in autumn into a "crystalline style"—a mass of reserve food-stuffs, and similar but less solid material is found in the intestine. On this supply the mussel tides over the winter. Some authorities, however, maintain that the style is a glandular secretion, protecting the lining of the gut from injury. The intestine, which has in part a folded wall like that of the earthworm, coils about in the foot, ascends to the pericardium, is surrounded by the ventricle of the heart, and ends above the posterior adductor at the exhalent orifice.

Vascular System.—The heart lies in the middle line on the dorsal surface, within a portion of the body-cavity called the pericardium, and consists of a muscular ventricle which has grown round the gut and drives blood to the body, and of two transparent auricles which receive blood returning from the gills and mantle. The colourless blood passes from the ventricle by an anterior and a posterior artery, flows into ill-defined channels, is collected in a "vena cava" beneath the floor of the pericardium, passes thence through the kidneys, where it loses nitrogenous waste, to the gills where it loses carbonic acid and gains oxygen, and returns finally by the auricles to the ventricle. The blood from the mantle, however, returns directly to the auricles without passing through kidneys or gills, but probably rid of its waste none the less. The so-called "organ of Keber" consists of "pericardial glands" on the epithelium of that cavity. They seem to be somehow connected with excretion. Many of the cells lining the blood-channels secrete glycogen, the principal product of the Vertebrate liver.

Respiratory System.—Lying between the mantle flaps and the foot there are on each side two gill-plates, whence the title Lamellibranch. They are richly ciliated, their internal structure is like complex trellis-work, their cavities communicate with the supra-branchial chamber. "Ctenidia" they are often called, because they are more than gills; not only are they surfaces on which blood is purified by the washing water-currents (a respiratory function), but some of their many cilia waft food-particles to the mouth (a nutritive function), and in the females the outer gill-plate shelters and nourishes the young larvæ (a reproductive function). The water-current is twofold—(1) through the gills to the supra-branchial chamber

and thence out again, (2) over the gills to the mouth, and thence into the supra-branchial chamber or in part into the food-canal. It is likely that the mantle has no small share in the respiration.

I shall not describe the precise structure and attachment of the gill-plates, but it is important to understand the following facts :—(*a*) a cross section of the two gill-plates on one side has the form of a W, one half of which is the outer, the other the inner gill-plate ; (*b*) each of these gill-plates consists of a united series of gill-filaments, which descend from the centre of the W and then bend up again ; (*c*) adjacent filaments are bound together by fusions and bridges both horizontal and vertical, so that each gill-plate becomes like a complex piece of basket-work ; (*d*) both gill-plates begin by the downward growth of filaments from a longitudinal "ctenidial axis," the position of which on cross section is at the median apex of the W ; (*e*) considering this mode of origin, and the much less complex gills of other bivalves, it is believed that it is most accurate to say that there is on each side one gill, consisting of two gill-plates formed from a series of united and looped gill-filaments.

The Excretory System consists of a paired kidney which used to be called the "organ of Bojanus." The two kidneys lie side by side beneath the floor of the pericardium. Each is a nephridium bent upon itself, with the loop posterior, the two ends anterior. The lower part of this bent tube is the true kidney ; it is dark in colour, spongy in texture, and excretes guanin and other nitrogenous waste from the blood which passes through it. It has an internal opening into the pericardium, *i.e.*, into part of the body-cavity. The upper part of the bent tube, lying next the floor of the pericardium, is merely a canal analogous with a ureter. It conveys waste-products from the glandular part to the exterior, and opens anteriorly just under the place where the inner gill-plate is attached to the visceral mass. As already mentioned, the "pericardial glands" probably aid in excretion, and possibly the same may be said of the mantle. It will be noticed that the pericardium has through the nephridia two indirect communications with the exterior.

The Reproductive Organs lie in the upper part of the foot, and are adjacent to the digestive gland. Ovaries and testes occur in different animals, and the two sexes are distinguishable, though not always very distinctly, by the greater whiteness of the testes and by slight differences in the shells. The females are easily distinguished when the larvæ begin to

accumulate in crowds in the outer gill-plates. The reproductive organs are branched and large; there are no accessory structures; on each side a genital aperture lies under that of the ureter.

Autumn and winter months seem to be the favourite periods of reproduction. The ova are squeezed out of the foot, and appear to be moved to the exhalent region, whence however they do not escape, but are crowded backward till they pass into the cavity of the outer gill-plate. At some stage they are fertilised by spermatozoa drawn in by the water-currents, though it is difficult to believe that this is entirely a matter of chance. Development takes place in the gill-cavity, which is often much distended with larvæ.

Development and Life-History.—The egg-cell is surrounded by a vitelline membrane, and is attached to the wall of the ovary by a tiny stalk, the insertion of which is marked on the liberated ovum by an aperture or micropyle, through which a spermatozoon may eventually enter.

The segmentation of the fertilised ovum is total but unequal. A number of small clear yolkless cells are rapidly divided off from a large yolk-containing portion, which remains for a while unsegmented. Eventually, however, a hollow ball of cells or blastosphere results.

A gastrula is formed from the blastosphere, by the indimpling of the lower, larger, yolk-containing cells, so that they are surrounded by the clearer small cells. As this gastrula is a-making, two large cells belonging to the lower series are set free into the cavity of the blastosphere.

The outer clear cells are ectodermic, and will form epidermis, nervous system, etc., the invaginated heavier cells form the endoderm which lines the gut; the two cells liberated into the cavity begin the median stratum or mesoderm, from which arise muscles, connective-tissue, etc.

If the development of *Anodonta* were like that of most of the bivalves whose development we know, its gastrula would grow into a trochosphere, and that would become a veliger. Instead of this, however, a peculiar larva results which is specially adapted to the risks of life in fresh water.

In the winter months these peculiar larvæ are abundant in the cavity of the outer gill-plate of the female mussels, a

convenient cradle, safe and yet continually freshened by water-currents. There, moreover, the developing embryos seem to be nourished by gelatinous stuff secreted from the gills. The larvæ remain in this shelter until they are ready for liberation, and may be retained beyond the usual period if there are no fish near. For it is to fish, such as sticklebacks and perches, that the liberated larvæ fix themselves. The larva is called a Glochidium.

The Glochidium has two triangular, delicate and porous, shell-valves, each with a spiny incurved tooth on its free edge. The valves clap together by the action of the adductor muscle. The mantle-lobes are very small, and their margins bear on each side three or four patches of sensory cells. The foot is not yet developed, but from the position which it will afterwards occupy there hang long attaching threads of "byssus," which serve to moor the larva. If it manage to anchor itself on the tail, fins, or gills of a fish, the Glochidium claps its valves and fixes itself more securely, and is soon surrounded by a pathological growth of its host's skin.

In this parasitic stage, a remarkable metamorphosis occurs. The sensory or tactile patches not unnaturally disappear; the byssus and the small gland which made it vanish, but a new byssus gland (which remains quite rudimentary in *Anodonta*) appears; the single adductor atrophies and is replaced by two; the foot and the gills make their appearance; the embryonic mantle-lobes increase greatly, or are replaced by fresh growths; and the permanent shell begins to be made.

After this metamorphosis, when the larva has virtually become a miniature adult, no longer so liable to be swept away, it drops from its temporary host to the bottom of the pond or river pool.

Classification of Bivalves.

Order I. Isomya. Adductor muscles approximately equal.

Sub-order I. Integripallia. The mantle's line of attachment to the shell is not broken by a sinus into which inhalent and exhalent siphons may be retracted, but in most these siphons are present.

Arca (Noah's Ark shell), *Unio* and *Anodonta* (fresh-water), *Lucina*, *Cyprina*, *Cardium* (cockle), *Cyclas* (fresh-water), *Tridacna*.

DIAGRAM XV.

The Fresh-water Mussel.

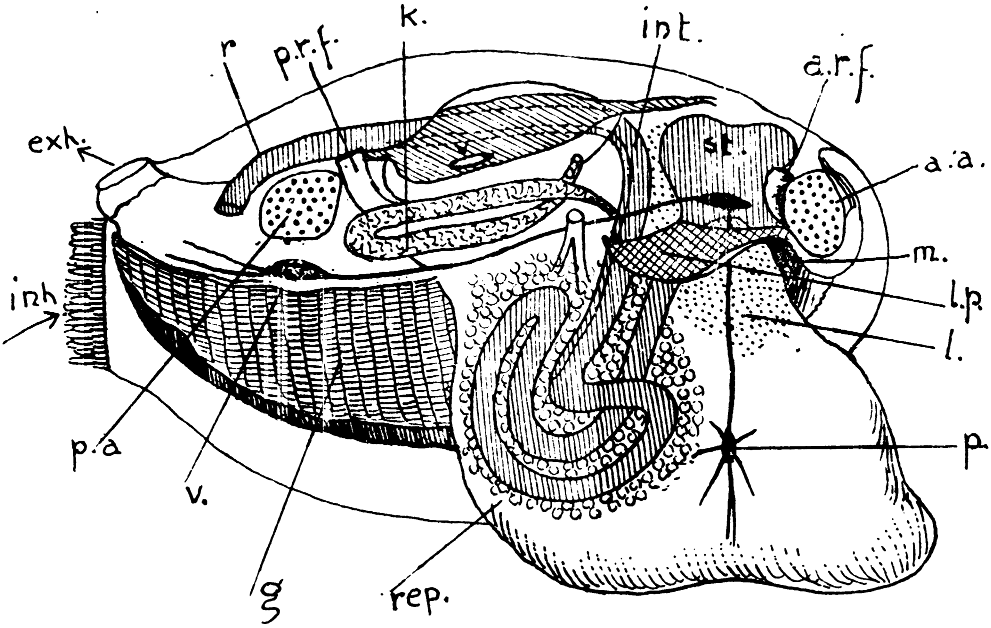
The figure of a dissected *Anodonta* (after Rankin) shows the following structures :—The inhalent aperture (*inh.*), the exhalent aperture (*exh.*), the mouth (*m.*), the gills (*g.*), the protruded foot, the anterior adductor (*a. a.*), the posterior adductor (*p. a.*), the retractor muscles of the foot, the cerebro-pleural ganglia above the mouth, the pedals (*p.*) in the foot, the viscerals (*v.*) below the posterior adductor, the labial palps (*l. p.*), the stomach (*st.*), the "liver" (*l*), the coils of the gut in the foot, the passage of the gut through the ventricle (*v.*), the rectum (*r.*), the kidney (*k.*), the reproductive organs (*rep.*) in the foot.

The cross-section (after Vogt and Yung) shows the external shell, the dorsal ligament (*l.*), the dorsal line of the mantle (*m.*), the pericardium (*p. c.*), the ventricle (*v.*), the enclosed gut (*g.*), the auricles (*a.*), the vena cava (*v. c.*), the sac of the kidney (*u.*), the gland of the kidney (*k.*), the nerves (*n.*) connecting cerebro-pleurals and viscerals, the gut (*g.*) in the foot (*f.*), the gills between foot and mantle.

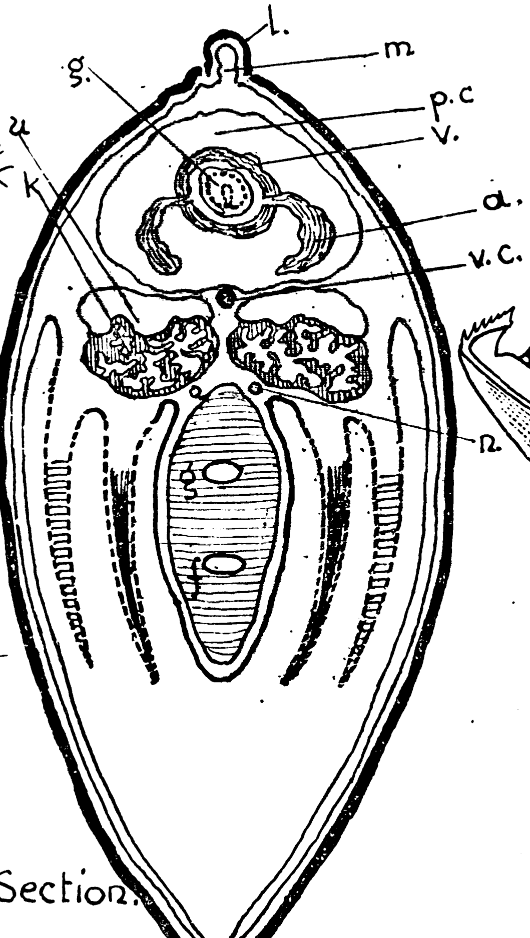
To the left is the nervous system (*nerv.*) with cerebro-pleurals (*c. p.*), pedals (*p.*), and viscerals (*v.*).

To the right is a Glochidium (from Balfour), showing the shell (*sh.*) with its spines (*s.*), the adductor muscle (*ad.*), the byssus (*by.*).

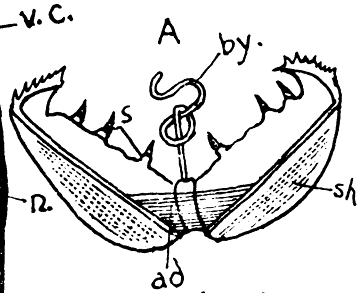
Freshwater Mussel.



Nerv.



Section.



Glochidium.

Sub-order 2. Sinupallia. The mantle's line of attachment to the shell is inflected by a sinus into which the large siphons are retracted.

Venus, *Mya*, *Saxicava* (a boring bivalve), *Solen* (razor-shell), *Pholas* (borer), *Teredo* (ship-worm), *Aspergillum* (watering-pot shell).

Order 2. HETEROMYA. The anterior adductor is much smaller than posterior, and siphons are rare.

Mytilus (edible mussel), *Modiola* (horse-mussel), *Lithodomus* (borer), *Dreissena*.

Order 3. MONOMYA. One adductor, no siphon.

Ostrea (oyster), *Anomia*, *Lima*, *Pecten* (scallop).

Class GASTEROPODA. Snails and slugs of many kinds, some living on land, others in water.

This class includes not only the common air-breathing snails and slugs, but the marine whelks and periwinkles, sea-hares (*Aplysia*) and "Nudibranchs" like *Doris*, limpets and ear-shells (*Haliotis*). To form a conception of Gasteropods from the snail alone, is apt to be very misleading.

In fact, there are so many different kinds of Gasteropods, that some division of the class is necessary before we can formulate general characters of much usefulness. Contrasted with bivalves, Gasteropods have usually a single shell, the head region is more or less distinctly developed, the mouth contains a rasping ribbon, and the foot, except in those adapted for free swimming, is a flat median sole on which the animal creeps or rests. In the foot distinct fore, mid, and hind regions are often well marked.

General Survey.

A. *Symmetrical Gasteropods* (*Isopleura.*)—The Gasteropods which seem most primitive are forms like *Chiton*, some species of which, easily known by their eight shell-plates, are not uncommon on the shore rocks. They are symmetrical, not lop-sided like most of the higher forms. The food-canal runs from one end of the body to the other; the gills, kidneys, auricles, and genital ducts are paired; two pairs of nerve-cords (pedal and visceral) run parallel to one another along the body, and the ganglia are but slightly developed. Agreeing in essential

features with *Chiton*, but much simpler are *Neomenia*, *Proneomenia*, and *Chætoderma*, in which the shell is represented only by small calcareous plates and spines in the skin. The three genera last mentioned suggest ideas about a hypothetical worm-like ancestor of Gasteropods.

B. *Asymmetrical Gasteropods* (*Anisopleura*).—Excepting *Chiton* and its allies, the Gasteropods are more or less asymmetrical. We must notice, however, (1) that this want of symmetry does not affect the head or the foot, but only the visceral mass of the body which is more or less twisted round to the right side toward the head; (2) this torsion must be distinguished from the frequent spiral twisting of the visceral hump and of the shell; (3) the torsion occurs in variable degree, and some forms, especially free-swimmers, have a superficial symmetry.

Professor Ray Lankester suggests an explanation of the asymmetrical torsion, which is none the less welcome that it does not seem to be quite consistent with his opposition to Lamarckian theory, or in other words, to the explanation of peculiarities of structure as the results of use, disuse, and conditions of life. I shall quote a few sentences from his highly appreciated article on Mollusca in the *Encyclopædia Britannica*:—

"This torsion is connected mechanically with the excessive vertical growth of the visceral hump, and the development upon its surface of a heavy shell. . . . . Whilst such a shell might retain its median position in a swimming animal, it and the visceral hump necessarily fall to one side in a creeping animal which carries them uppermost. The shell and visceral hump in the Anisopleura incline normally to the right side of the animal. As mechanical results, there arise a one-sided pressure and a one-sided strain, together with a one-sided development of the muscular masses which are related to the shell and foot. Both the torsion through a semicircle of the base of the visceral dome, and the continued spiral growth of the visceral dome itself, which is very usual in the Anisopleura, appear to be traceable to these mechanical conditions."

The above explanation seems very reasonable, but however the lop-sidedness of most Gasteropods has arisen, its existence must be realised if the other anatomical characters are to be understood. For the torsion has numerous more or less direct results. Thus (*a*) the food-canal ends on the right side, usually far forward on the neck; (*b*) the primitively left gill, brought round to the right by torsion, usually atrophies; (*c*) the primitively right kidney seems to disappear, while the primitively left, brought round to the right by torsion, persists; at any rate there is only one; (*d*) in one series of Gasteropods the visceral nerve-loop, running from the cerebral and pleural to the visceral ganglia, is "caught in the twist" and twines like a figure 8 (Streptoneural condition), in the others the same visceral loop is short and untwisted (Euthyneural condition).

To sum up, excepting a small sub-class of symmetrical forms (*e.g.*, *Chiton*), Gasteropods are asymmetrical molluscs, in which the visceral mass has undergone more or less forward torsion toward the right side. This torsion profoundly affects the food-canal, gills, kidneys, and often the

nervous system and other parts. In a large number, the visceral hump on the back is twisted spirally, and the adult shell likewise. Not a few, however, especially free-swimmers, are superficially symmetrical, and the adult shell may be cap-like, degenerate, or absent. The head-region is well-developed and symmetrical; it contains several concentrated pairs of ganglia and bears sense-organs. The mouth contains a rasping ribbon or radula. The foot is symmetrical. It is usually a flat median creeping sole, and generally contains a large mucous gland.

Among these asymmetrical Gasteropods, there is great variety of form and habit.

(*a*) The Streptoneura, in which the visceral nerve-loop is implicated in the visceral torsion and twisted like the figure 8, in which, moreover, the sexes are separate, include limpets (*Patella*), ear-shells (*Haliotis*), the vegetarian pond-snail (*Paludina*), the carnivorous "buckie" (*Buccinum*), the sea-weed eating periwinkle (*Littorina*), the cowries (*Cypræa*), and many others, besides the divergent free-swimming carnivorous Heteropods, *e.g.*, *Atlanta*, *Carinaria*, *Pterotrachea*.

(*b*) In the Euthyneura, the visceral nerve-loop is not twisted but often very short; the shell is generally light and sometimes absent in the adult; the food-canal is not twisted so far forwards as in (*a*), and sometimes ends medianly and posteriorly; the reproductive organs, moreover, are hermaphrodite. The sea-hare (*Aplysia*), such nudibranchs as *Doris* and *Eolis*, are types of what are often called opisthobranchs (gill behind the heart). But the Euthyneura also include many forms without gills in which the mantle cavity is a respiratory chamber, as in the fresh-water snails (*e.g.*, *Planorbis*, *Limnæus*), the land snails (*Helix*), the slugs (*Limax*, *Arion*).

Apart from these Gasteropods, and yet not so far apart as to form a separate class, many authorities rank the sea-butterflies or Pteropods, which we shall notice afterwards.

Mode of Life.—From the number of diverse types which we have already mentioned, it is evident that few general statements can be made about the life of Gasteropods. We are safe in saying, however, that though the majority are

sluggish when compared with Crustaceans, they are active when compared with Lamellibranchs.

The locomotion effected by the contractions of the muscular foot is usually a leisurely creeping, but there are many gradations between the activity of Heteropods in the open sea, the gliding of fresh-water snails (*Limnæus*) foot upwards across the surface of the pool, the explorations of buckies (*Buccinum*) on the sand of the shore, and the extreme passivity of limpets (*Patella*) which move only for short distances at a time from their resting-places on the rocks.

Statistics are not very interesting nor reliable, for there is much difference of opinion as to limits of species and varieties, but we may notice that the number of terrestrial snails and slugs, breathing the air directly by means of a pulmonary-chamber, is estimated at over 6000 living species, while the aquatic Gasteropods are reckoned at about 10,000, most of which are marine. Of this myriad, about 9000 are streptoneural (we may recall the vast array of shells in the museum cases), the relatively small minority are euthyneural opisthobranchs and nudibranchs, with light shells or none. The Heteropods and some opisthobranchs live in the open-sea; the great majority of aquatic Gasteropods frequent the shore and the sea-bottom at relatively slight depths; the deep-sea forms are comparatively few.

Gasteropods rarely feed at such a low level as bivalves do, indeed some of them are fond of eating bivalves. Most prosobranchs (streptoneural), with a respiratory siphon and a shell notch in which this lies, are carnivorous, witness the buckies (*Buccinum*) and "dog-whelks" (*Purpura*), whose voracity you can watch in the shore-pools; on the other hand, those without this siphon, and with an unnotched shell-mouth, feed on plants, witness the seaweed-eating periwinkles (*Littorina*). This correlation is not rigorously true, but it suggests reflection as to the plausibly two-sided connection between very vigorous habits and carnivorous diet, more sluggish habits and vegetarian diet, and finally between passivity and a diet of organic débris and animalcules. The vegetarian habits of most land snails and slugs are known to all. Many Gasteropods, both marine and terrestrial, are very voracious and indiscriminate in their

meals; others are as markedly specialists or epicures. Some marine forms, partial to Echinoderms, have got over the difficulty of eating such hard food by secreting dilute sulphuric acid, which is said to change the carbonate of lime in the starfish into the more brittle and readily pulverised sulphate. Only a few Gasteropods are parasitic, *e.g.*, *Eulima* and *Stylifer* on Echinoderms, and the extremely degenerate *Entoconcha mirabilis*,—within the Holothurian *Synapta*.

Life-History.—The eggs of Gasteropods are usually small, without much yolk, but surrounded by a jelly, the surface of which hardens. In the snail and in some others there is an egg-shell of lime.

Sexual union occurs between hermaphrodites as well as between separate sexes, and fertilisation is effected inside the genital duct. Development sometimes proceeds within the parent, but in most cases the fertilised eggs are laid in gelatinous clumps, or within special capsules. The free-swimming *Ianthina* carries the eggs in capsules attached to a large raft-like float towed by the foot. On the shore one often finds numerous egg-capsules of the "buckie" (*Buccinum undatum*) united in a ball about the size of an orange. Under the ledges of rock are many little yellowish cups, the egg-capsules of the dog-whelk (*Purpura lapillus*). In the buckie and whelk, and in some other forms, there is a struggle for existence—an infant cannibalism—in the cradle, for out of the numerous embryos in each capsule only a few reach maturity, those that get the start eating the others as they develop.

The segmentation of the ovum is total, but somewhat unequal; a gastrula is formed by invagination or by overgrowth according as there is less or more yolk; the gastrula becomes a trochosphere with a pre-oral ring of cilia; the trochosphere grows into a veliger with a lobed ciliated cushion or velum, a visceral dome, a dorsal shell-gland which soon disappears, and an incipient ventral foot. In terrestrial snails like *Helix*, the life-history is abbreviated. In the water-snail *Limnæus*, Ray Lankester has detected the persistence of the velum in the circumoral lobes of the adult.

Past History of Gasteropods.—As the earth has grown

older the Gasteropods have increased in numbers. A few have been disinterred from Cambrian rocks; thence onwards they increase. Most of the Palæozoic genera are now quite extinct, but many modern families trace their genealogy to the Cretaceous period. Those with respiratory siphons were hardly, if at all, represented in Palæozoic ages, and the terrestrial air-breathers are comparatively modern. Zoological statisticians estimate the number of Gasteropods at 23,000, of which 7000 are extinct, 16,000 alive. But besides the numerical success which may be inferred from these figures, it is important to notice that not a few types have persisted from early ages.

General Interest.—I do not like to leave the discussion of Gasteropods without at least saying that their shells are often very beautiful in colour and graceful in form, the reason of which can be found only in that harmony which fills the heart of things. As voracious animals, with irresistible raspers, Gasteropods commit many atrocities in the struggle for existence and decimate many plants. Professor Stahl shows, however, that there are more than a dozen different ways in which plants are saved from snails,—by crystals, acids, ferments, etc.; and like an orthodox Darwinian he regards these plants as the survivors of a multitude, which did not become sufficiently gritty or poisonous. As food and bait many Gasteropods are very useful; their shells have supplied tools and utensils and objects of delight; the juices of *Purpura* and *Murex* furnished the Tyrian purple, more charming than all aniline.

A type of GASTEROPODA—The garden snail (*Helix aspersa*), or the edible snail (*H. pomatia*).

Mode of Life.—Our very common garden-snail (*H. aspersa*) and its larger neighbour species (*H. pomatia*), rare in England but abundant on the continent, are so like one another except in size, that the same description will serve for both. They are thoroughly terrestrial animals, breathing air directly within a pulmonary chamber, and are slowly drowned when

immersed in water. Their food consists of leaves and other parts of plants, but they sometimes indulge strange vagaries of appetite. They are hermaphrodite, but their sexual relations are by no means simple. The breeding time is spring, and the eggs are laid in the ground. In winter, snails bury themselves, cementing the mouth of their shell with hardened mucus and a little lime, and fall into a state of "latent life" in which the heart beats very feebly. In such a state they have been known to survive for years.

General Appearance.—A snail actively creeping shows a well-developed head, with two pairs of retractile horns or tentacles of which the longer bear eyes. We may see and even hear the snail browsing. The foot, by the muscular contraction of which the animal creeps, is very large; it leaves a slimy trail of mucus. The viscera are extruded as usual in a dorsal hump, and this hump is spirally coiled, and is protected by the spiral shell within which the entire animal retracts itself on slight provocation. Around the mouth of the shell is a very thick mantle margin or collar, by which the continued growth of the shell is secured. On the right side of the expanded animal, close to the anterior edge of the shell, there is a large aperture through which air passes into and out of the mantle cavity. Within the same aperture is the terminal opening of the ureter. The food-canal ends slightly below and to the right of the pulmonary aperture. All the three openings are virtually together. The anterior termination of ureter and food-canal is one of the results of the torsion which we have already described. But still further forward, at the end of a slight groove which runs along the right side of the neck, indeed quite close to the mouth, is the genital aperture. Lastly, an opening just beneath the mouth leads into the large mucous-gland of the foot.

The Shell, a right-handed spiral, is a cuticular product made and periodically enlarged by the mantle margin. Chemically it consists of carbonate of lime and an organic basis (conchiolin). The outermost layer is coloured, without lime, and easily rubbed off; the median layer is thickest and looks like porcelain; the innermost layer is pearly. The twisted cavity of the shell is continuous, and the viscera extend to

DIAGRAM XVI.

GASTEROPODA—ESPECIALLY THE SNAIL.

At the top to the left is a section of the shell of *Helix*, showing the columella.

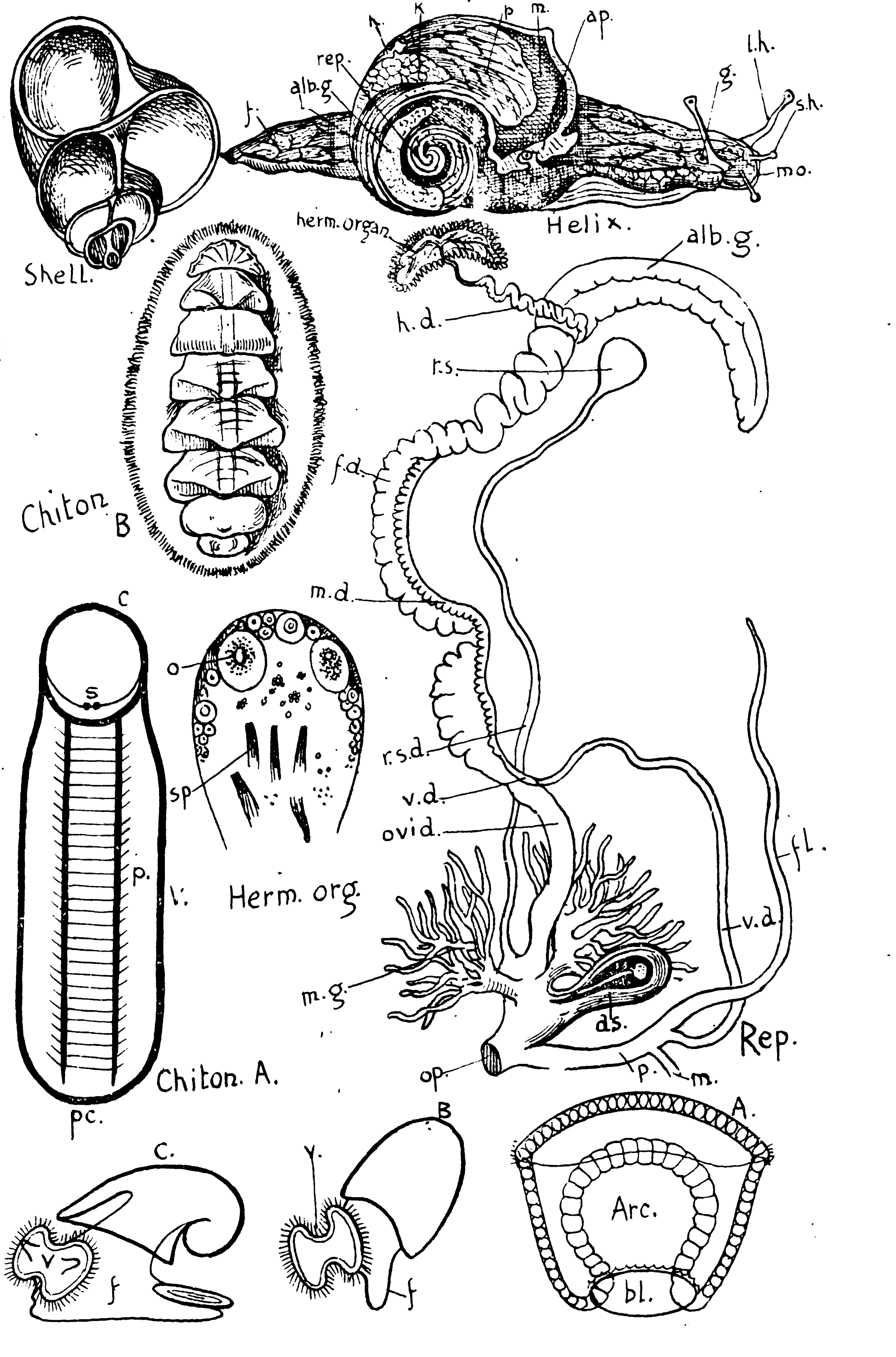
To the right is a partially dissected *Helix* (after Vogt and Yung), showing the month (*mo.*), the long eye-bearing horns (*l. h.*), the short horns (*s. h.*), the genital aperture (*g.*), the pulmonary aperture (*ap.*), the reflected mantle (*m.*), its vascular wall (*p.*), the kidney (*k.*), the heart (*h.*), the reproductive organ (*rep.*) at the top of the visceral spire, the albumen gland (*alb. g.*), the posterior part of the foot (*f.*).

Chiton B. shows the eight shell-plates (from Lankester). *Chiton A.* shows the cerebral ring (*c.*), the pedal nerve-cords (*p.*), the visceral nerve-cords (*v.*), the sub-lingual ganglia (*s.*), (from Lankester, after Hubrecht).

The reproductive organs of *Helix* (in part after Vogt and Yung), show the hermaphrodite organ or ovo-testis (*herm. organ*), the hermaphrodite duct (*h. d.*), the albumen gland (*alb. g.*), the female side of the common duct (*f. d.*), the male side of the common duct (*m. d.*), the vas deferens (*v. d.*), the flagellum (*fl.*), the penis (*p.*), its muscle (*m.*), the oviduct (*ovid.*), the mucous glands (*m. g.*), the receptaculum seminis (*r. s.*) and its duct, the dart-sac (*d. s.*), the genital opening (*op.*).

At the foot, *A* represents the incipient trochosphere of *Paludina* (after Lankester), showing the archenteron (*Arc.*) and blastopore (*bl.*), *B* and *C* (after Gegenbaur) are two forms of veliger, showing foot (*f.*), and velum (*v.*).

Gasteropod.



k
p
m.
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rep.
alb.g
f.
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g.
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Shell.
herm. organ.
Helix.
alb.g.
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Chiton B
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the uppermost and oldest part. As the shell is gradually made, the inner walls of the coils form a central pillar (columella), such as you may see on a staircase, and to this the animal is bound by a strong muscle. Many Gasteropods bear a horn-like shell lid (operculum) on their foot, but *Helix* has none; the "epiphragm," with which the shell is sealed in winter, consists of hardened mucus, plus phosphate and a smaller quantity of carbonate of lime. It is formed very quickly from the collar region when cold weather sets in, has no organic connection with the animal such as binds an operculum to the foot of the whelk, and is loosened off in the mildness of spring.

External Appearance after the Shell is Removed.—If the shell is removed carefully so that nothing is broken except the columellar muscle, many structures can be seen without any dissection. The skin of the head and foot should be contrasted, (*a*) with the thick collar of the mantle, (*b*) with the loose roof of the mantle or pulmonary chamber, (*c*) with the exceedingly delicate, because much stretched and always protected, skin of the visceral hump. It is important to realise that the snail has an enlargement of the liver and a great rupture-like hump of viscera on the dorsal surface, that this has been coiled spirally, and that there is a yet deeper torsion forward to the right.

A great part of the hump consists of the greenish brown digestive gland, in which the bluish intestine coils behind the mantle chamber; on the left lies the triangular and greyish kidney; the whitish reproductive organ lies in the second last and third last coil of the spiral.

The Skin.—We have just noticed that the skin varies greatly in thickness. It consists of a single layered epidermis and a more complex dermis, including connective tissue and muscle fibres. There are numerous cells from which mucus, pigment, and lime are secreted, the two latter are especially abundant on the collar, where they contribute to the shell which is gradually increased in that region. The mucous glands of the skin must not be confused with those which are very numerous in the foot and form a secretion which oozes out by a duct opening just beneath the mouth.

Muscular System.—The most important muscles are—(*a*)

those in the foot, (*b*) those which retract the animal into its shell, and are attached to the columella, (*c*) those which work the radula in the mouth, (*d*) the retractors of the horns, and (*e*) the retractor of the penis. The muscle fibres usually appear unstriated. There is much connective tissue, some of the cells of which contain glycogen, pigment, and lime.

The Nervous System is concentrated in a hardly analysable ring round the gullet. Careful examination shows that this ring consists dorsally of a pair of cerebral ganglia, connected ventrally with a pair of pedals and a pair of pleuro-viscerals, which, according to some authorities, have a median abdominal ganglion lying between them.

The cerebrals give off nerves to the head, *e.g.*, to the mouth, tentacles, and otocysts, and also two nerves which run to a pair of small buccal ganglia, lying beneath the junction of gullet and buccal mass. The pedals give off nerves to the foot, the viscerals to the mantle and posterior organs.

Sense-Organs.—An eye, innervated from the brain, is situated on one side of the tip of each of the two long horns. It is a cup invaginated from the epidermis, lined posteriorly by a single layer of pigmented and non-pigmented retinal cells, filled with a clear vitreous body perhaps equivalent to a lens, and closed in front by a transparent "cornea," and strengthened all round by a firm "sclerotic." How much a snail sees we do not know, but it is easy to prove that it detects swift movements. Though the eye is by no means very simple, the snail can readily make another if the original be lost, and this process of regeneration has been known to occur twenty times in succession.

The otocysts appear as two small white spots on the pedal ganglia. Each is a sac of connective tissue, lined by epithelium which is said to be ciliated in one region, containing a fluid and a variable number of oval otoliths of lime, innervated by a very delicate nerve from the cerebral ganglia.

No osphradium or smelling patch, comparable to that which occurs at the base of the gills in most Molluscs, has been discovered in *Helix*. But every one can see that the snail is repelled or attracted by odours; it shrinks from

turpentine, it smells strawberries from afar. We know, moreover, where this sense of smell is "located," for a dis-horned snail has none. The tips of both pairs of horns bear sensory cells connected with ganglionic tissue and nerve-fibres within.

Other sensory cells, probably of use in tasting, lie on the lips; and there are many others, which may be called tactile, on the sides of the foot, and on various parts of the body. In short, the snail is diffusely sensitive.

Alimentary System.—The snail feeds for the most part on the leaves of plants. It files these by means of the radula or toothed ribbon which lies in the mouth, and grasps the débris with its lips.

The radula is a long strip of membrane, bearing several longitudinal rows of little chitinoid teeth. It rests on a cartilaginous pad on the floor of the mouth-cavity, and is moved (backwards and forwards, and up and down) in a curve, by protractor and retractor muscles. The whole apparatus, including radula-teeth, membrane, and pad, is called the odontophore. The work of rasping wears the radula anteriorly, but it is continually being added to posteriorly within a radula sac which projects like a knob from the floor of the oral or buccal cavity. Its action on leaves may be compared very roughly to that of a file, but its movements within the mouth also produce a kind of suction which draws food particles inwards. In this suction the muscular lips and the abundant cilia in the mouth-cavity assist.

Altogether apart from the radula, lying on the upper surface of the buccal chamber, sometimes visible when the snail opens its mouth, is a hard, crescent-shaped jaw-plate. Against this the radula seems to work.

The ducts of two large salivary glands open on the dorsal surface of the buccal cavity, and there are numerous distinct glandular cells close to the entrance of the two ducts. The salivary glands are large lobed structures, and extend far backward on the crop. They consist of hundreds of glandular cells or unicellular glands, which secrete a clear fluid stuff. This travels up the ducts, and is forced, in part at least by muscular compression, into the buccal cavity. While some say that this fluid converts starch into sugar

(after the usual fashion of saliva), other authorities deny that it has any effect upon the food.

The gullet extends backward from the buccal cavity, and expands into a storing crop; this is followed by a stomach surrounded by the digestive gland; thence the intestine extends, and after coiling in the visceral hump, passes forward to end on the right side anteriorly beside the respiratory aperture. The digestive tract is muscular, and in part ciliated internally.

As we have repeatedly mentioned, a large part of the visceral spiral is occupied by the so-called "liver." This is a digestive gland of many qualities, producing juices which digest all kinds of food, making glycogen, storing phosphate of lime, and containing a greenish pigment called enterochlorophyll. It is possible that the phosphate of lime may be used to form the autumnal epiphragm, but the most important fact is that the gland is more than a "liver," more even than a "hepato-pancreas," it is a complex digestive gland, which may be called "poly-enzymatic," *i.e.*, productive of several digestive ferments or enzymes.

Vascular System.—The blood of the snail contains some colourless amœboid cells, and a respiratory pigment called hæmocyanin, which gives the oxidised blood a blue tint.

The heart, consisting of a ventricle and an auricle, lies within a pericardial chamber on the dorsal surface to the left side behind the mantle cavity.

From the ventricle pure blood flows by cephalic and visceral arteries to the head, foot, and body, passes into fine ramifications of these arteries, and thence into spaces among the tissues. Authorities differ as to the existence of capillaries, but the distinction between these and narrow channels is of no physiological importance. From spaces among the tissues the blood is collected in larger venous spaces, and eventually in a pulmonary sinus around the mantle cavity, on the roof of which there is a network of vessels. There the blood is purified. Most of it returns directly to the auricle by a large pulmonary vein, but some passes first through the kidney.

Respiratory System.—Most Gasteropods, *e.g.*, the dog-whelk (*Purpura*), the buckie (*Buccinum*), the periwinkle

(*Littorina*), breathe by gills covered over by a fold of the mantle. The snail being entirely terrestrial has a pulmonary or lung cavity, formed by the usual mantle-flap. On the roof of this cavity the blood-vessels are spread out, and the blood is purified. Air passes into and out of the pulmonary chamber by the respiratory aperture, which lies, as we have mentioned, on the right side of the body. When the animal is retracted within its shell, the freshening of the air in the pulmonary chamber must take place by slow diffusion, but when the snail extends itself at full length, the chamber must be rapidly filled with air, and even more rapidly emptied when the animal withdraws into the shell again.

The Excretory System consists of a triangular greyish kidney, which lies behind the pulmonary chamber between the heart and the rectum. It is a sac, with plaited walls, and certainly excretes nitrogenous waste-products, which pass out by a long ureter running along the right side of the pulmonary chamber, and opening close beside the anus. From two sources the kidney is supplied with pure blood, from the pulmonary chamber, and from the heart by a renal artery. As in other Molluscs, the kidney communicates by a small aperture with that part of the body-cavity which surrounds the heart and is known as the pericardial sac. This pericardium has therefore an indirect communication with the exterior.

The Reproductive System.—The snail is hermaphrodite, and its reproductive organs exhibit much division of labour.

(*a*) The essential reproductive organ (or *ovo-testis*) is readily seen as a whitish body near the apex of the visceral spire. It consists of numerous cylindrical follicles, in each of which both ova and spermatozoa are formed, but not at the same time. Simultaneous formation of elements so different would be a physiological impossibility.

(*b*) A much convoluted readily broken *hermaphrodite duct* of a white colour conducts the germ-cells from the ovo-testis, and leads to the base of a large yellowish albumen gland.

(*c*) This tongue-shaped *albumen gland* varies in size with the age and sexual state of the snail. It forms gelatinous proteid material, which appears to envelope and perhaps nourish the ova.

(*d*) The ova and spermatozoa pass from (*b*) towards the head along a *common duct*, but not at the same time. Moreover their paths are different, for the portion of the duct down which the ova travel is much plaited, while the path which the spermatozoa follow is a less prominent, more granular groove, incompletely separated anatomically from the other. Both paths are glandular, and the glands on the male side are often called prostatic.

(*e*) At the base of this common duct, a distinct *vas deferens* diverges to the left, twists round the root of the right long horn, and leads into a muscular *penis*, which can be protruded at the single genital aperture and retracted by a special muscle. At the point where the vas deferens enters the penis, a long process or *flagellum* is given off. It is like the lash of a whip, and is as long as the common duct. Within it a spermatophore is partly formed, which seems to be completed in the penis. This spermatophore is laden with a large number of spermatozoa, and is transferred by the penis into the genital aperture of another snail.

(*f*) Continued from the oviducal side of the common duct, there is a separate ciliated *oviduct*. This has a shorter course than the vas deferens, and ends in the common genital aperture. Before it reaches this, however, the oviduct is associated with two structures. The first of these is a long process, as long as the common duct beside which it runs, in appearance suggesting the flagellum, but expanding at its free end into a globular sac—the *receptaculum seminis*. It is into this long duct and sac that a spermatophore from *another* snail passes, and is after some days dissolved, liberating hundreds of spermatozoa. By these spermatozoa the ova of this snail are fertilised at some part of their course. The second structure associated with the female duct is a conspicuous *mucous gland*, formed of two sets of finger-like processes. The mucous secretion of this gland is very abundant during copulation, and as it contains not a little lime, it is possible that it may form the calcareous shells of the eggs.

(*g*) Finally; between the entrance of oviduct and penis into the terminal aperture, which is hardly large enough to be called a chamber, there lies a firm cylindrical structure, larger than the penis and with muscular walls. It is the

Cupid's Dart-Sac, and contains a pointed calcareous arrow (*spiculum amoris*), which is jerked out as a preliminary excitant to copulation. The dart is sometimes found adhering to the skin of a snail, and after copulation the sac is empty—soon however to be refilled.

When two snails pair, the genital apertures are dilated, the protruded penis of one is inserted into the aperture of the other, and the transference of a spermatophore is thus effected.

The eggs are laid in the earth in June and July. Each measures about a quarter of an inch in length, and is surrounded by gelatinous material acquired in the oviduct, and by an elastic but calcareous shell.

Segmentation is total but slightly unequal. As the snail is a terrestrial Gasteropod there is no trochosphere larva nor more than a slight hint of the characteristic Molluscan velum. A miniature adult is hatched in about three weeks. The study of development may be more profitably attempted in the pond snail *Limnæus*, where gastrula, trochosphere, and veliger can be readily seen.

Classification of Gasteropoda.

Sub-Class I. Gasteropoda Isopleura (= Amphineura).

Bilaterally symmetrical Gasteropods, elongated in form, with mouth at one end of the body and anus at the other.

The pedal and visceral nerve-cords run straight, parallel to one another, along the whole body. Ganglionic swellings are slight or even absent.

The auricles, the gills, the nephridia, the genital ducts, are paired and bilaterally symmetrical.

Examples.—*Chiton*, *etc.* (Polyplacophora), with eight dorsal shell plates, each developed in a shell-sac comparable to the single one of other Molluscs. Lodged in the shell there are sometimes hundreds of eyes, but there are none on the head. The mantle flap which hangs down the sides, often bears spines and knobs, some of which may be sensory. Sheltered by the mantle, along the sides of the body are many gills, each with "smelling patch," or "osphradium," at its base. The odontophore is well-developed.

Some small species are common on the rocks of British coasts. *Neomenia* and *Proneomenia* are small, flat forms, whose shell is represented solely by microscopic plates or spicules of lime. The mantle is

much reduced, the odontophore is feebly developed. *Chætoderma* is more elongated and cylindrical; its shell is represented by minute spines, its mantle is reduced, the foot is abortive, there are only two gills, the odontophore is very slightly developed, and has a radula with a single tooth. The last three forms have been dredged from considerable depths. They suggest in some ways how Gasteropods may be linked to "worm" types.

Sub-Class II. GASTEROPODA ANISOPLEURA.

Gasteropods which are more or less asymmetrical. The head and foot remain bilateral, but the visceral hump with its mantle fold is twisted round to the right and forwards. Thus the anus, the gills, the nephridia, and the genital aperture lie on the right side, and more or less anteriorly. The originally right gill comes to lie to the left, and the originally left gill usually atrophies. A similar fate seems to befall the originally right nephridium. The main torsion must be distinguished from the spiral twisting which the visceral hump often exhibits, and from the associated spiral coiling of the shell. Moreover, a superficial bilateral symmetry is sometimes acquired by free-swimming forms, *e.g.*, Heteropods. The reproductive organ and genital duct are single. There is usually a pedal gland in the foot.

I. Streptoneura. Visceral nerve loop twisted; sexes separate.

(1) Zygobranchs. Both gills present or absent. A rudimentary nephridium sometimes persists on the left side. Small visceral dome.

Examples.—*Patella* (limpet), *Haliotis* (ear-shell).

(2) Azygobranchs. Originally right gill and left nephridium persist. Large visceral dome and shell.

Examples—

Pond-snail (*Paludina*); whelk (*Littorina*); buckie (*Buccinum*); dog-whelk (*Purpura*); cone-shells (*Conus*); *Murex*; *Ianthina*.

Also the pelagic Heteropods, with foot adapted for swimming, *e.g.*, *Atlanta* (large shell), *Carinaria* (small shell), *Pterotrachea* (no shell).

II. Euthyneura. Visceral nerve loop not twisted, often short; hermaphrodite; shell often light and lost in adult.

(1) Opisthobranchs. Small visceral hump; rarely any shell in the adult; anus behind and heart in front of the gill.

Examples—

(*a*) With developed mantle fold, usually with delicate shell (Tectibranchia), *e.g.*, *Aplysia*, *Bulla*, *Phyllidia*.

(*b*) With atrophied mantle and no shell on adult (Dermatobranchia or Nudibranchs), *e.g.*, *Doris*, *Eolis*, *Phyllirhoe*.

(2) Pulmonata. Air-breathing, without gill, with respiratory mantle-cavity, *e.g.*, *Helix* (snail), *Limax* (grey slug), *Arion*, black slug; *Limnæus*, *Planorbis*, and *Ancylus* (common fresh-water snails).

Appendix to the Gasteropoda, probably to be included among them :—

PTEROPODA. Winged Snails, Sea-butterflies.

Free-swimming pelagic molluscs, with secondarily acquired bilateral symmetry. They swim by two large side lobes of the foot ("epipodia"), the median region being much reduced. The visceral dome is long, rarely in a spiral, sometimes covered with a light shell, sometimes naked. There are no gills. Anal, nephridial, and genital apertures lie anteriorly, and usually on the right. The animals are hermaphrodite. They are carnivorous in habit, often swim actively in shoals, and occur in all seas. They afford food for whales, etc., and the shells of some are abundant in the ooze.

Examples—

Thecosomata, with mantle fold and shell ;—*Hyalea*, *Cymbulia*.
Gymnosomata, without mantle fold or shell in the adult ;—*Clio*, *Pneumodermon*.

Class SCAPHOPODA.

Very different from all Gasteropods are the Scaphopoda, of which *Dentalium* (Elephant's tooth shell) is the commonest genus. Their position is uncertain. Some place them nearer bivalves, others nearer Cephalopods. They live at considerable depths off the coasts of many countries. The tubular shell is shaped like an elephant's tusk, and is open at both ends. The anterior end is directed downwards in the sand. The concave side is dorsal, the convex ventral. With the form of the shell the state of the mantle corresponds, for its two folds, originally separate as in bivalves, fuse into an almost complete tube. The shell also is at first an incomplete tube. The small cylindrical head bears at its extremity a mouth surrounded by numerous "tentacles," while at the base of the head there is a double cluster of ciliated contractile processes possibly representing gills. The foot is long, with three small terminal lobes. It is used in slow creeping. There are cerebral, pedal, and pleural ganglia, near one another in the head, and the visceral loop is long. Sense-organs are represented by otocysts beside the pedal ganglia. There is an odontophore with a simple radula. The food consists of minute animals. There is no heart, but colourless blood circulates in the spaces of the body. There are two nephridial apertures, one on each side of the anus; the nephridial chamber is perforated by the intestine. The sexes are separate; the reproductive organ is simple and dorsal in position ; the elements pass out by a duct which opens into one of the nephridial ducts. The gastrula is succeeded by a free-swimming stage, in which there is a hint of a velum and a rudimentary shell-gland.

Examples.—*Dentalium*, *Entalium*. About forty widely distributed species are known. *Dentalium entale* occurs off British coasts. The genus occurs as a fossil from Carboniferous (or perhaps earlier) strata onwards.

Class Cephalopoda. Cuttlefishes.

This class includes Squid and Calamary, Octopus and Sepia, the Argonaut and the pearly Nautilus, besides hundreds of extinct forms—such as Belemnites and Ammonites.

Characteristics.—Cephalopods swim in the sea, or lurk and creep among the rocks, voracious devourers of many kinds of prey—hard crabs and blubbery jellyfish.

They cannot be mistaken for any other animals, for their forms and their ways are alike peculiar.

Like most free-swimming molluscs, they are bilaterally symmetrical, but part of the "foot" has come to surround the head, and is divided into numerous "arms." Another (middle) part of the foot forms a partially or completely closed tube—the "siphon" or "funnel"—through which water gushes out from the mantle-cavity, driving the animal backward. The muscular mantle-flap sheltering the gills is posterior in position, and the visceral mass, though without any spiral coiling, is much elongated in a direction which is anatomically dorsal and posterior, but which points forwards when the cuttlefishes propel themselves through the water.

A chambered external shell serving as a house is present in *Nautilus* alone among living Cephalopods. In *Spirula*, there is a spiral, chambered shell, but it is covered by the mantle, and is too small to serve as a house. Most of the extinct forms lived in shells, tubular, or curved like a horn, or chambered like that of *Nautilus*; most of the modern forms seem to be more active than their ancestors, and their shells have degenerated. I shall summarise what Ray Lankester says as to the degeneration. It seems that the shell was reduced in size, became surrounded by the mantle in a secondary shell-sac, that the walls of this sac secreted lime which disguised the enclosed shell (*e.g.*, Belemnites), that the original shell disappeared while the secondary deposits of lime were left (*Sepia*), that even this secondary calcareous deposit may disappear, leaving an organic chitinous plate (*e.g.*, the pen of *Loligo*), and that even this may disappear, *e.g.*, in *Octopus*. One must be careful to note that the "cuttle-bone" of *Sepia* is not a rudiment of an old shell, and that the secondary shell-sac is different from the embryonic shell-gland.

In the head the cerebral, pleural, and pedal pairs of ganglia are concentrated around the gullet, and protected by a cartilaginous box, analogous after a fashion to the Vertebrate skull. As we would expect in active adventurous animals, eyes and other sensitive structures are generally well-developed.

The mouth is armed with hard jaws like a parrot's beak, and there is the usual rasping tongue or odontophore.

Two pairs of gills in *Nautilus*, one pair only in the others lie posteriorly in the mantle cavity, and it is there that the food-canal, the kidney ducts, and the genital duct all end.

The vascular system is very well developed, the heart with two auricles and a ventricle lies in an unusually large pericardial chamber. The kidneys are large and saccular.

The sexes are separate. The male elements are made up in packets or spermatophores, which are usually transferred to one of the "arms," more or less modified for copulatory purposes. The eggs are large, and often surrounded by capsules.

Considering the large quantity of yolk in the egg, we do not wonder that the development differs much from that of bivalves and Gasteropods; the trochosphere and veliger stages are not recognisable as such.

There are at least two sets—(1) the Nautiloids, of which the Pearly Nautilus is the only living representative, and along with which the extinct Ammonites are usually associated; (2) the Octopod and Decapod cuttlefishes, along with which the extinct Belemnites are included.

A Type of Cuttlefish—*Sepia officinalis*.

Mode of Life.—This common cuttlefish is widely distributed, especially in warmer seas like the Mediterranean. Unlike the *Octopus*, which usually lurks passively, *Sepia* swims actively, gently moving the fins which fringe the body, or jerking itself energetically backwards by the outgush of water through the funnel. It likes the light, and is sometimes attracted by lanterns. The beautiful colours change according to external conditions and internal emotions; and a plentiful discharge of ink often covers its

retreat from an enemy. Its food includes fish, other molluscs, and crabs. In spring the female attaches her encapsuled eggs to sea-weeds and other objects, and often comes fatally near the shore in so doing. The "cuttles" are caught for food and bait. The "cuttle-bone" and the pigment of the ink-bag are sometimes utilised.

External Appearance.—A large *Sepia* measures about ten inches in length and four or five in breadth; the body, fringed by a fin, is shaped like a shield, the broad end of which bears a narrower head, with eight short and two long sucker-bearing arms. Besides the diffuse pigment-cells, there are zebra-like bands across the "back," and the living animal is certainly beautiful. The large eyes, the parrot-beak-like jaws protruding from the mouth, the spout-like funnel on the neck, and the mantle-cavity are conspicuous.

The true orientation of the different regions in *Sepia* is not obvious. If the "arms" surrounding the mouth be divided portions of the anterior part of the "foot," the *ventral* surface is that on which the animal rests when we make it stand on its head. We can fancy how the "foot" of a snail might grow forward and surround the mouth, so as to bring that into the middle of the sole. Then the visceral mass has been elongated in an oblique dorso-posterior direction, so that the tip of the shield, directed forward when the cuttle jerks itself away from us, represents in anatomical strictness the *dorsal* surface tilted backwards. The side of lighter colour, marked by the mantle-cavity and the siphon or funnel, is *posterior* and slightly ventral; the banded and more convex side on which the cerebral ganglia lie in the head region, and on which the shell lies concealed in the visceral region, is *anterior* and slightly dorsal.

The Skin is remarkably beautiful, because of numerous actively changeful pigment-cells or chromatophores, each of which is expanded or contracted according to the state of fine muscle-fibres which extend all round in radial directions. Girod insists on calling these connective fibres, and perhaps they are illustrations of a merging of these two kinds of tissue. It is probable that these chromatophore cells have some protoplasmic spontaneity of their own, but the controlling fibres seem to be affected by nervous impulses from the central ganglia. As the cells contract or dilate the colours

change, and the beauty is enhanced by numerous "iridocysts" or modified connective tissue cells, with fine markings which cause iridescence.

The Muscular System.—The cuttlefish is very muscular, notably about the arms, the mantle flap, and the jaws. With great quickness it seizes its prey by throwing out its two long arms, which are often entirely retracted within pouches. With great force it jerks itself backwards by contracting the mantle-cavity, and making the water gush out through the pedal funnel. This mode of locomotion is very quaint. At one time the mantle-cavity is wide, and you can thrust your fingers into its gape; when about to contract, this gape is closed by a strange double hook-and-eye arrangement; contraction occurs, and the water no longer free to leave as it entered gushes out by the funnel, the base of which is within the mantle-cavity. In rapid succession gush follows gush, but all silently, though you may hear the *Sepia* "blow" when it is removed from the water and gives a final mantle gasp in air. Another muscular development is hardly less interesting, that of the suckers on the arms. They are muscular cups, borne on little stalks (unstalked in *Octopus*, *etc.*), well innervated, and able to grip with a tenacity which in the giant cuttlefishes is dangerous even to men. The inner edge of the cup-margin bears small chitinous teeth. Each cup acts as a sucker, in a fashion which has many analogues, by increasing the size of the cavity after the margin has been applied to some object or other. The external pressure is then greater than that within the cup, and the little teeth keep the attachment from slipping.

Skeletal System.—An internal skeleton, a new item of structure, is represented by supporting cartilaginous plates in various parts of the body, especially (*a*) in the head, round about the brain, arching over the eyes, enclosing the "ears"; (*b*) at the bases of the arms; (*c*) as a crescent on the neck; (*d*) at the hook-and-eye arrangement of the mantle flap; (*e*) along the fringing fins. Ramified "stellate" cells lie in the structureless transparent matrix of the cartilage.

On the shore one often finds as a relic of its bearer, the "cuttle-bone" or sepiostaire, and one sees it often in the windows of bird-dealers' shops. It is given to cage-birds to

peck at for lime, and is used as a polishing powder, as pounce, as a dentifrice and cosmetic. It lies on the convex and more coloured side of the animal, covered over by skin. In outline it is somewhat ellipsoidal, thinned at the edges like a flint axe-head, and with curved markings which indicate lines of growth. In the very young *Sepia*, it consists wholly of the organic basis conchiolin, but this is only obvious at the edges of the fully formed structure which contains in addition lime and gas. It has a very spongy texture, and though it may give the cuttle some backbone, it is probably of more use as a float.

Internal Appearance.—When we cut open the mantle flap and fold the halves back, we at once see the two plume-like gills, and the lower end of the siphon. The dark outline of the ink-bag followed along towards the head leads our eyes to the end of the food-canal. Near this are the external apertures of the two kidneys and of the genital duct. On each side of the base of the funnel lies a very large and unmistakeable "stellate" ganglion. Removing the skin as carefully as possible over the whole visceral region between the gills, and taking precautions not to burst the ink-sac, we see the median heart, the saccular kidneys, contractile structures or branchial hearts at the base of each gill, and the essential reproductive organs near the apex of the visceral mass. Disturbing the arrangement of these organs, we can follow the food-canal with its stomach, liver, pancreas, etc.

The Nervous System is concentrated in three pairs of ganglia which surround the gullet,—cerebral on the dorsal and anterior side, pedal and pleuro-visceral on the ventral and posterior side.

The cerebral ganglia are three-lobed, and are connected anteriorly by two commissures with a "supra-pharyngeal" ganglion, which gives off nerves to the mouth and lips, and is connected also with an "infra-pharyngeal" ganglion. Secondly, the cerebral ganglia are connected by short double commissures, with the pedals and pleuro-viscerals on the other side of the gullet.

The following chief nerves are given off from the central system :—

(1) The very thick optic nerves are given off from the commissures between cerebrals and pleuro-viscerals, and lead to a large optic ganglion at the base of each eye.

(2) The nerves to the "arms" are given off by the pedal ganglion, and this is one of the reasons which have led most morphologists to regard these arms as portions of the "foot."

(3) Two large visceral nerves from the pleuro-visceral ganglia form a visceral loop, and give off many branches to the gills and other organs. From the same source arise two mantle nerves, each of which ends in a large stellate ganglion.

Sense-Organs.—The eyes are large and efficient. They present a marked but by no means perfect resemblance to Vertebrate eyes, and thus illustrate how the same sort of structure may be developed (surely not by the natural selection of indefinite fortuitous variations), in different ways and in divergent groups. In cuttlefishes, the eyes lie on the sides of the head, protected in part by the cartilage surrounding the brain, and in part by cartilages on their own walls.

The eye is a sensitive cup arising in great part from the skin. The internal surface of this cup is a complex sensitive retina innervated from the optic ganglion. In the cavity of the cup there is a clear vitreous humour.

The mouth of the cup is closed by a light-focussing lens, supported by a "ciliary process." The lens seems to be formed strangely enough in two parts—an outer and an inner plano-convex lens. The pupil or hole in front of the lens is fringed by a contractile iris.

The outer wall of the optic cup is ensheathed by a strong supporting layer—the sclerotic, which is in part strengthened by cartilage, covered by a silvery membrane, and continued into the iris.

There is no true cornea, at least not like that of the Vertebrate eye, but the skin forms a complete lid over the eye, and in this lid there is a little hole by which water enters and bathes the outer part of the lens, as the aqueous humour does in our eyes.

Round about the optic ganglion there is a strange "white body," which seems to be a fatty cushion on which the eye rests.

The two ear-sacs, containing a spherical otolith and a fluid, sometimes with calcareous particles, are enclosed in part of the head cartilage, close by the pedal ganglia, but are apparently innervated from the cerebrals.

DIAGRAM XVII.

CEPHALOPODA.

The figure *Sepia* (from Vogt and Yung) shows the posterior aspect of the body, the funnel (*f.*), the entrance to the mantle-cavity (*m. c.*).

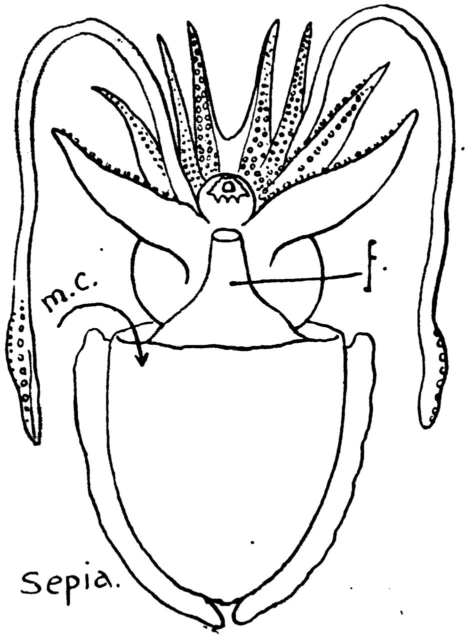
The diagrammatic section (*Sect.*) beneath shows the flexure of the gut, the ganglia (*ga.*) around the gullet, the stomach (*st.*), the dorsal and posterior reproductive organs (*rep.*), the ink-bag (*i. b.*), the gills (*g.*), the mantle-cavity (*m. c.*).

The section of the eye (from Gegenbaur, after Hensen) shows the two layers of the retina (*re.*), the lens (*l.*), the ciliary process (*ci.*), the iris-cartilage (*i. c.*), the silvery membrane (*arg.*), the cornea (*c.*), the white body (*w.*), the optic ganglion (*o. g.*), the optic nerve (*o. n.*), the cartilage of the optic capsule (*c.* and *k.*), the cephalic cartilages (*c. c.*).

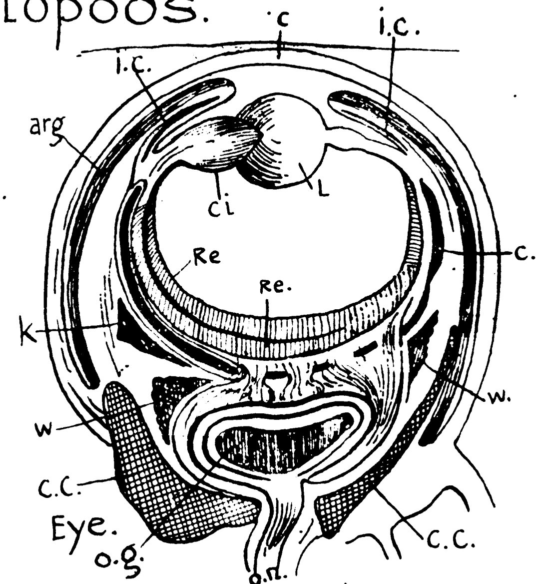
Diagram *Circ.* (after Nuhn) suggests the course of the blood ;—*A.* the auricles, *V.* the ventricle, *ao.* the aorta, then the distribution in the body and collection in veins (*v.*), then the passage through the kidney (*k.*), and through the gills (*br.*) to the auricles again.

The series of hearts (after Gegenbaur) shows the specialisation of auricles. *A* shows the dorsal vessel and entrant transverse vessels in a worm, *B* the ventricle and so-called auricles of *Nautilus*, *C* the heart of a bivalve or of *Loligo*, *D* of *Octopus*, *E* of the Snail.

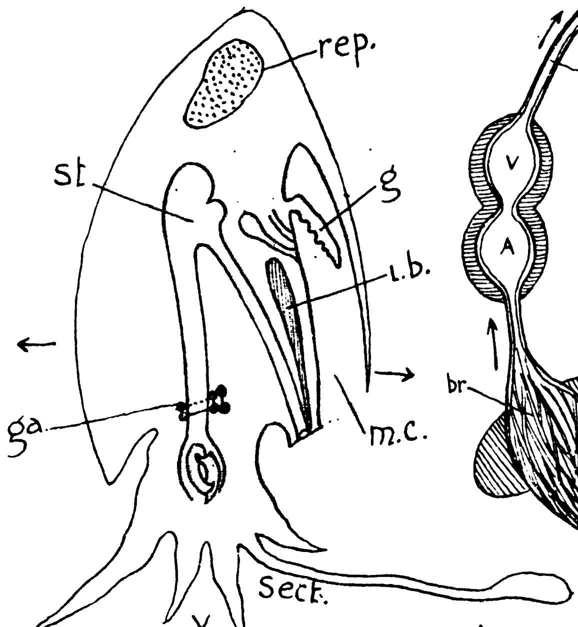
Cephalopods.



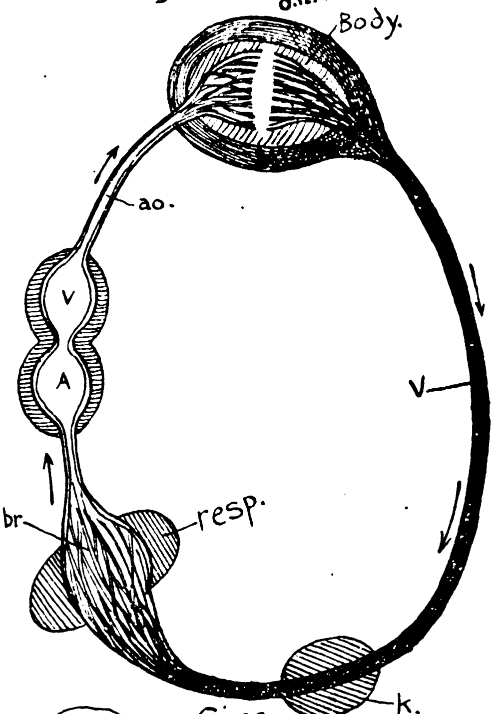
Sepia.



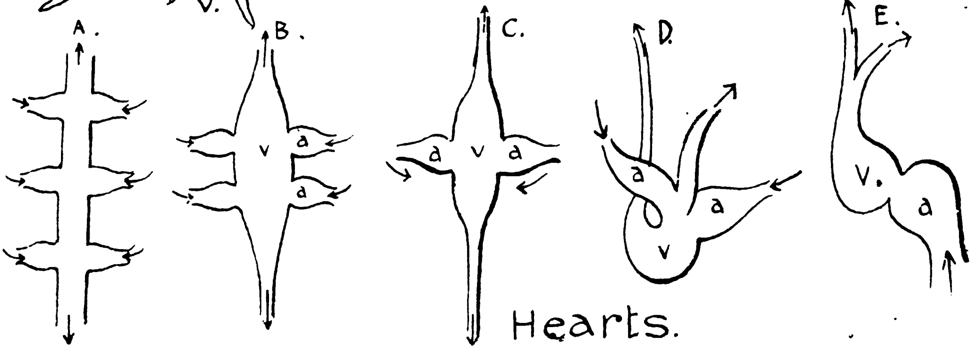
Eye.



Sect.



Circ.



Hearts.

A ciliated "olfactory sac" lies behind each eye, and with it a special ganglion is associated.

Finally, there are tactile or otherwise sensitive cells on various parts of the body, especially about the arms.

Alimentary System.—The cuttlefish eats food which requires tearing and chewing, and this is effected by the chitinous jaws worked by strong muscles, and by the toothed rasper moving on a muscular cushion. The mouth lies in the midst of the arms, bordered by a circular lip. Through the ganglionic mass passes the narrow gullet, leading into the globular stomach. The stomach is immediately followed by another dilatation ("pyloric sac"), and the intestine curves headwards again to end far forward in the mantle cavity. There do not seem to be any glands on the walls of the food-canal, the stomach has a hard cuticle, the digestion which takes place there must therefore be due to the digestive juices of the glandular appendages. Of these the most important is usually called the liver; it is bilobed, and lies in front of the stomach attached to the œsophagus. Its two ducts conduct the digestive juice to the region where stomach, "pyloric sac," and intestine meet, and these ducts are fringed by numerous vascular and glandular appendages which are called "pancreatic," as usual without sufficient evidence. Far forward, in front of the large digestive gland, lie two little white glands on each side of the gullet. Their ducts open into the mouth near the radula, their secretion is not known to have any effect on the food. It is obviously better to call them (with Krukenberg) "pharyngeal mucus glands," than to continue repeating the title "salivary glands," for which there is no warrant. At the other end of the food-canal, the ink-sac full of black pigment, probably of the nature of waste-products, opens into the rectum close to the anus. This ink-sac may be called a much enlarged anal gland, for while most of the bag is made of connective tissue and some muscle fibres, a distinct gland is constricted off at the closed end, and the neck is also glandular.

Vascular System.—The blood of *Sepia* is bluish, owing to the presence of hæmocyanin in the serum; the blood cells are colourless and amœboid. The median but somewhat oblique ventricle of the heart drives the blood forward

and backward to all parts of the body. It reaches the tissues by capillaries, and apparently also by lacunar spaces. The venous blood of the head region is collected in an annular sinus round the bases of the arms, and passes towards the heart by a large vein, which divides into two venæ cavæ covered with spongy appendages. Joined by similar vessels from the apical region of the viscera, each vena cava enters a "branchial heart" at the base of each gill. The branchial heart is contractile, and drives the venous blood through the gills, whence purified it returns by two contractile auricles into the ventricle. There are valves preventing back flow from the ventricle to the auricles, or from the arteries to the ventricle. Each branchial heart bears an enigmatical glandular structure known as a "pericardial gland," possibly an excretory or incipiently excretory organ. The course of the blood differs from that in the mussel and snail in this, that none returns to the heart except from the respiratory organs. In the spongy outgrowths of the venæ cavæ, the interesting parasite *Dicyema* is found.

Respiratory System.—The blood is purified by being exposed on the two feather-like gills which are attached within the water-washed mantle cavity. These are anything but simple, for their surface is plaited and folded to a much greater degree than we might at first imagine, the water penetrates them very thoroughly, the course of the blood is intricate. At their base there is some glandular tissue, which those impatient with enigmas have credited with blood-making powers.

The Excretory System is difficult to dissect and to explain. On each side of the anus there is a little papilla through which uric acid and other waste-products ooze out into the mantle-cavity, or we may say into the water. A bristle inserted into either of these two papillæ leads into a large sac—the excretory or nephridial sac. But the two sacs are united by two bridges, and they give off an unpaired dorsal elongation, which extends as far back as the reproductive organs.

The dorsal wall of each nephridial sac becomes intimately associated with the spongy appendages of the venæ cavæ, and follows their outlines faithfully. It is likely that waste material passes from the blood through the spongy appendages into the nephridial sacs.

Into the terminal portion of each nephridial sac, a little below its aperture at the urinary papilla, there opens by a ciliated funnel another sac, which is virtually the body-cavity. It surrounds the heart and other organs, and is often called the viscero-pericardial cavity. Through the kidneys or nephridial sacs it is in indirect communication with the exterior.

Reproductive System.—The sexes are separate, but there is not much external difference between them, though the males are usually smaller, less rounded dorsally, and with slightly longer arms. When mature the male is easily known by a strange modification on his fourth left arm. The essential reproductive organs are unpaired, and lie towards the apex of the visceral mass in the viscero-pericardial cavity.

The testis—an oval yellowish organ—lies freely in a peritoneal sac near the apex of the visceral mass. From this sac, the spermatozoa pass along a closely twisted duct—the vas deferens. This expands into a twofold "seminal vesicle," and gives off two blind outgrowths, of which one is called the "prostate." The physiological interest of these parts is that within them the spermatozoa begin to be compacted into packets. These packets are found within the next region—the spermatophore sac which opens to the exterior to the left of the anus. Each spermatophore is like a transparent worm. We may compare it to a little glass-tube, closed at one end, drawn out and somewhat twisted at the other; within the tube at the closed end is a bag of dust attached to and kept in its place by a sort of spiral spring; this is prevented from expanding by the fact that its upper end is fixed by cement in the mouth of the tube. Now if the cement be soluble in water, and the tiny machine be thrown into a basin, the spring will expand violently as the cement is dissolved, the bag of dust will be torn out and scattered. Somewhat similar but more complex is the spermatophore—with its clear case, its contained bag of spermatozoa, its spring-like arrangement, and its explosiveness in water. Even, indeed, on a moist scalpel or on a slide, these strange but efficient bombs will explode. The liberated spermatozoa are of the usual type.

The ovary—a large rounded white organ—lies freely in a peritoneal sac near the apex of the visceral mass. From this sac the eggs pass along a short direct oviduct, which opens into the mantle cavity to the left of the anus. Associated with the oviduct, and pouring viscid secretion into it, are two large "nidamental glands," of foliated structure. Close beside these are accessory glands, of a reddish or yellowish colour, with a median and two lateral lobes; while at the very end of the oviduct are two other glands. All seem to contribute to the external equipment of the egg.

The spermatophores pass from the genital duct of the male to the fourth left arm, which becomes covered with them and quaintly modified. This is usual among cuttle-fish, and in some, such as *Argonauta* and *Tremoctopus*, the modified arm with its load of spermatozoa is discharged bodily into the mantle cavity of the female. There its discoverers described it as a parasitic worm "*Hectocotylus*." In *Sepia*, however, the modified arm is not discharged, but simply thrust into the mantle cavity of the female. The spermatophores burst, and the liberated spermatozoa fertilise the eggs apparently in the mantle cavity.

The laid eggs are enclosed within separate black capsules containing gelatinous stuff, but the stalks of the capsule are united so that a bunch of "sea-grapes" results.

Second Type of CEPHALOPODA. The Pearly Nautilus (*Nautilus pompilius*).

The shells of the pearly Nautilus are common on the shores of warm seas, but the animals are very rare. Naturalists do not seem to know how to get them, though the natives of Fiji and the New Hebrides, who appreciate their flesh, trap them successfully in lobster-pots baited with crustacean or sea-urchin. The animal creeps or swims gently along the bottom at no great depth, and its appearance on the surface, "floating like a tortoise-shell cat," is probably the result of storms. It is called "pearly" because of the innermost layer of the shell. This is exposed after the soft organic stratum and the median layer which bears bands of colour have been worn away, or dissolved in a dolphin's stomach, or artificially treated with acid.

The beautiful shell is a spiral in one plane, divided into a set of chambers, in the last of which the animal lives, while the others contain gas. The young creature inhabits a tiny shell curved like a horn; it grows too big for this, and proceeds to enlarge its dwelling, meanwhile hitching itself forward in the older part, and forming a door of lime behind it. This process is repeated again and again; as an addition is made in front, the animal draws itself forward a little, and shuts off a part of the chamber in which it has been living. The compartments seen on a divided shell are not exactly successive chambers, they are fractions of successive chambers abandoned and partitioned off as more space was gained in front. Moreover, all the compartments are in communication by a median tube or siphuncle, which is in part calcareous.

It has been suggested, that "each septum shutting off an air-containing chamber is formed during a period of quiescence, probably after the reproductive act, when the visceral mass of the Nautilus may be slightly shrunk, and gas is secreted from the dorsal integument so as to fill up the space previously occupied by the animal."

The only other living Cephalopod which has a shell like that of the Nautilus is *Spirula*. In this form the shell is again chambered and spirally coiled in one plane. But it is without a siphuncle, and lies enveloped by folds of the mantle.

There can be no confusion between the beautiful shell of the cuttlefish called the paper Nautilus (*Argonauta argo*) and that of our type. For it is only the female Argonaut which bears a shell, it is made by two of the arms not by the mantle, it is not chambered, it is a shelter for the eggs—a cradle not a house.

It is instructive also to compare the Nautilus shell with that of some Gasteropods, for there also chambers may be formed. But these arise from secondary alterations of an originally continuous spiral, and the resemblance is never very striking. The fresh-water snail *Planorbis* has an unchambered shell spirally coiled in one plane, but in this and in similar Gasteropods, the foot is turned towards the internal curve of the coil, while that of Nautilus is directed externally.

There are only about half a dozen living species of *Nautilus*, but there are many hundred fossils of this and

allied genera. This list is usually swelled by the addition of the extinct Ammonites, but there are some reasons for believing that these belong to the cuttlefish section of Cephalopods.

CEPHALOPODA.

TETRABRANCHIATA (*Nautilus*).	DIBRANCHIATA (*Sepia*, *Octopus*, *etc.*).
All extinct except one genus—*Nautilus;* the extinct forms are usually ranked as Nautiloid and Ammonoid.	Numerous living genera, ranked as Decapods or Octopods; along with the former the extinct Belemnites are included.
Shell external, chambered, straight or bent or spirally coiled. That in which *Nautilus* lives has been described, with its siphuncle, gas-containing compartments, etc.	No living Dibranchiate lives in a shell. The shell is internal even in the extinct Belemnites, and in modern forms it occurs in various degrees of degeneration (cf. *Spirula*, *Sepia*, *Loligo*) or is quite absent (Octopoda).
The part of the foot surrounding the mouth bears a large number of lobes, which carry tentacles in little sheaths, and no suckers.	The part of the foot surrounding the mouth is divided into ten or eight arms, which carry suckers, stalked in Decapods, sessile in Octopods.
The two mid-lobes of the foot form a siphon, but they are not fused into a tube.	The two mid-lobes of the foot fuse to form a completely closed tubular siphon or funnel.
The eye is an open sac without a lens. There are two "osphradial papillæ" or smelling patches at the bases of the gills.	The covering of the eye may be perforated, but the mouth of the retinal cup is closed by a lens. There are no osphradia, though there may be "olfactory pits" behind the eyes.
Two pairs of gills; two pairs of nephridial sacs; two genital ducts (the left rudimentary).	One pair of gills; one pair of nephridial sacs; two oviducts in Octopoda and *Ommastrephes;* two vasa deferentia in *Eledone moschata;* in others an unpaired genital duct.
The viscero-pericardial sac opens to the exterior by two apertures.	The viscero-pericardial sac opens into the nephridia by two pores.
The heart has no auricles, and there are no branchial hearts.	The heart has two auricles, and there are branchial hearts.
No ink-bag.	An ink-bag.

Classification.

Order I. Tetrabranchiata (see preceding page).

Family I. Nautilidæ. *Nautilus* alone alive; but a great series of fossil forms, *Orthoceras—Trochoceras.*

Family II. Ammonitidæ. All extinct, but with shells well preserved, so that long series can be studied. They furnish striking evidence of progressive evolution in definite directions. Examples—*Bactrites*, *Ceratites*, *Baculites*, *Hamites*, *Ammonites*, *Heteroceras.*

Order II. Dibranchiata (see preceding page).

Sub-Order Decapoda. Eight shorter and two long arms. Suckers stalked and strengthened by a horny ring. Large eyes with a horizontal lid. Body elongated, with lateral fins. Mantle margin with a cartilaginous "hook and eye" arrangement. Some sort of internal "shell."

With calcareous internal "shell." *Spirula*; *Sepia*; extinct *Belemnites.*

With horny internal "shell."

(*a*) Eyes with closed cornea, *e.g.*, *Loligo.*

(*b*) Eyes with open cornea, *e.g.*, *Ommastrephes.*

Sub-Order Octopoda. Eight arms only. Suckers sessile without horny ring. Small eyes with sphincter-like lid. Body short and rounded. No "hook-and-eye" arrangement. No internal "shell."

Examples—*Octopus*, *Eledone*, *Argonauta.*

CHAPTER XV.

CHARACTERS AND AFFINITIES OF VERTEBRATES.

Vertebrata—"*Backboned*" *Animals*.

THE distinction between Vertebrates and Invertebrates is a very old one, for even Aristotle distinguished mammals, birds, reptiles and amphibians, and fishes as "blood-holding," from cuttlefish, shell-bearing animals, crustaceans, insects, etc., which he regarded as "bloodless." He was, indeed, mistaken about the bloodlessness, but the distinctiveness of the higher animals first mentioned has been recognised by all subsequent naturalists, though it was first precisely expressed in 1797 by Lamarck.

Yet it is no longer possible to draw a boundary line between Vertebrates and Invertebrates with that firmness of hand which characterised the early or indeed the pre-Darwinian classifications. For we now know—(1) that Fishes and Cyclostomata (hag and lamprey) do not form the base of the Vertebrate series, but that the lancelet (*Amphioxus*), and the sea-squirts (Tunicata) must be included in the Vertebrate alliance; (2) that a yet simpler worm-like form, *Balanoglossus*, has several essentially Vertebrate characteristics; (3) that some of the recognised Invertebrates especially Chætopods and Nemerteans, exhibit some hints of affinities with Vertebrates. The limits of the Vertebrate alliance have been widened, and though the recognition of their characteristics has become more definite, not less so, the apartness of the sub-kingdom has disappeared.

It does not matter much whether we continue (with Ray Lankester) to retain the familiar title Vertebrata, or adopt that of Chordata, provided that we recognise—(1) that it is

among Fishes first that separate vertebral bodies appear in the supporting dorsal axis of the body; (2) that as a characteristic, the vertebral column is less important than another supporting rod, the notochord, which precedes the vertebral column in the history alike of the race and of the individual. Nor need we object to the popular title backboned, provided we recognise that the adjective "bony" is first applicable among Fishes, and not even to them all.

Characteristics of Vertebrata.

(1) *Dorsal Nerve-Cord.*—In such Invertebrates as earthworm and crayfish, that is to say in Annelids and Arthropods, the long ganglionated nerve-cord lies along the *ventral* surface, and is connected anteriorly with the dorsal or cerebral ganglia by a double commissure through which runs the gullet. This is characteristic of Invertebrates.

In Vertebrates, however, the central nervous system, consisting of brain and spinal cord, lies on the *dorsal* surface, and is tubular in structure. In *Balanoglossus* there is a dorsal nerve-cord, and a ventral as well; in Tunicates the nerve-cord lies along the dorsal surface, but except in the *Appendicularia* type it degenerates in the adults; in *Amphioxus* it persists, but there is hardly any brain; in higher Vertebrates the brain and spinal cord are well developed.

(2) *Dorsal Axis* or *Notochord.*—Beneath the ectodermic spinal cord, in all young Vertebrates from Tunicates upwards, there lies an endodermic supporting rod or notochord. In *Balanoglossus* (Hemichordata) it is very slightly developed, in the anterior region of the body; in Tunicates (Urochordata, *i.e.*, with notochord in the tail), it is confined to the posterior part of the body, and degenerates in the adults except in the *Appendicularia* type; in *Amphioxus* (Cephalochordata) it persists and extends from the tip of the head to the tip of the tail as a continuous rod; in Cyclostomata (hag and lamprey) it persists unconstricted as a gristly rod; in some Elasmobranchs and Ganoids the same is true; in all other Vertebrates it is constricted into seg-

ments. But it never becomes the backbone; it is only the internal scaffolding around which the backbone is built. The backbone appears alike in history and in the individual as a substitute for the notochord. For, from Cyclostomata onwards, the external (mesodermic) sheath of the notochord gains in importance, constricts and tends to obliterate what it surrounds. In Fishes, and in some Amphibians and Reptiles, part of the notochord persists in the adult, but in all other cases the backbone, developed from the notochordal sheath, almost entirely replaces the notochord.

(3) *Gill-Clefts.*—From the pharynx of *Balanoglossus* numerous respiratory slits open to the exterior; in *Appendicularia* and young Tunicates there is a pair, which persist in the type named, but are replaced by numerous secondary slits in the others; in *Amphioxus* the slits are very numerous; in Cyclostomata and Fishes they are limited to a maximum of eight; they are still to be seen and are used in all young Amphibians, and also in those forms which retain their gills even after they acquire the lungs which all adult Amphibians possess. In higher Vertebrates, whose embryos have an amnion and allantois, there are no longer any gills, and the gill-clefts are wholly embryonic and virtually functionless. In some cases they do not open.

(4) *Brain-Eye.*—Many Invertebrates have well-developed eyes, and those of cuttlefishes are very like those of Vertebrates. But the eyes of Invertebrates arise in greater part as insunk skin-cups, whereas those of Vertebrates are in greater part outpushed vesicles of the brain. Yet this marked difference is less than at first sight appears, since the hollow brain is itself but an insunk tube of ectoderm. There is no eye in *Balanoglossus*, nor in *Amphioxus*, nor in adult Tunicates.

(5) *Ventral-Heart.* — Many Invertebrates have well-developed hearts, but these are formed from a modification of *dorsal* blood-vessels, whereas those of Vertebrate animals are *ventral.* In *Balanoglossus*, however, what is sometimes called a heart is dorsal. In Tunicates the heart is a very simple tube, which drives the blood first in one direction and then in another. In *Amphioxus* there is no definitely developed heart, but there are many contractile regions on the blood-vessels. From Cyclostomata upwards the heart is well-developed.

(6) *Segmental Symmetry.*—Like Annelids and Arthropods, Vertebrates are segmented animals, as is evidenced by the distribution of nerves and ganglia, by the gill-slits and their supporting arches, by the muscle-segments of the embryo at least, by the vertebral bodies and skull-segments, and by the arrangement of the nephridia which compose the embryonic kidney. There is, however, no very distinct segmentation in *Balanoglossus*, nor in Tunicates. The precise meaning of segmentation is uncertain. It secures reproduction in some worms, etc., by the liberation of posterior segments; in other cases, it probably increases the co-ordinating power, and it may make the reparation of injuries more possible. It seems to depend on conditions of growth, of which we have very little understanding. Segmentation occurs in so many ways and in so many classes, that it is likely that it originated repeatedly and independently at different stages in the evolution of animals.

Origin of Vertebrates.—It is not at present possible to trace the path along which Vertebrates have evolved. There are several rival theories, but it is not certain that even any one of them need be correct. Only very sanguine people talk about the ancestor of all the Vertebrates, as if he would be almost certainly discovered next year, but except those who are easily satisfied, and those who have staked heavily on one theory, all acknowledge that the pedigree of Vertebrates is still obscure. It seems possible that among various sets of Invertebrates, there were convergences towards Vertebrate structure, and perhaps it is better to regard these not as inconsistent but simply as manifold affinities of which one or none may represent the line of descent.

I take it as proved that *Amphioxus* is a Vertebrate, that the Tunicata, especially in their youth, are Vertebrates, and that *Balanoglossus* has at least more remarkable affinities with Vertebrates than have the other claimants, viz., Annelids, Nemerteans, and perhaps even some Arthropods. In regard to the relative simplicity of Tunicates and *Amphioxus*, it must be remembered that degeneration seems to have been by no means uncommon in the history of animals. There is no doubt that the Tunicates are victims of degeneration, for few of them fulfil the promise of their youth, and some authorities believe that *Amphioxus* is also a degenerate form, "a weed in the vertebrate garden."

In accounting for the origin of a Vertebrate from an Invertebrate type, one of the greatest difficulties to be faced is, that the nerve-cord is *dorsal* in the former, while it is *ventral*, or at least never dorsal in the latter. The suggestion naturally occurs that a Vertebrate may correspond to an inverted Invertebrate, to a worm wallowing back downwards, to an insect swimming feet upwards. De Blainville and Geoffroy St. Hilaire suggested this possibility early in the century, and it has never since been far from the thoughts of speculative morphologists.

The "Vertebrate" Series (to be read from below upwards)—

Craniata, *i.e.*, with skulls.

Gnathostomata, *i.e.*, with jaws.

BIRDS
- Carinatæ (flying).
- Ratitæ (running).
- Saururæ (extinct forms).

REPTILES
- Crocodilia (crocodiles, etc.)
- Ophidia (snakes).
- Lacertilia (lizards, etc.)
- Rhynchocephalia—*Sphenodon.*
- Chelonia (tortoises, etc.)
- Extinct Reptiles (many orders). → ?

Sauropsida.

MAMMALS.

3. Eutheria, Placentalia, Monodelphia, the higher or placental mammals.
2. Metatheria, Marsupialia, Didelphia, Kangaroos, etc., with prematurely born young, usually nurtured in pouches.
1. Prototheria, Monotremata, Ornithodelphia, oviparous, *Ornithorhynchus* and *Echidna.*

Mammalia.

Amniota, embryos with amnion and allantois.

↑ ?

FISHES.—
- Dipnoi (double breathing mud-fishes). → ?
- Teleostei (modern bony fishes).
- Ganoidei (sturgeon, etc.)
- Elasmobranchii (incl. Holocephali), skate, shark, etc.

AMPHIBIANS.
- Anura (tailless frogs, etc.)
- Urodela (tailed newts, etc).
- Gymnophiona (wormlike *Cæcilia*, etc.)
- Extinct Stegocephala (*Labyrinthodon*, etc)

Ichthyopsida (Fishes and Amphibians).

CYCLOSTOMATA (Round-Mouths) without true jaws.

Myxine, hag-fish. *Petromyzon*, lamprey.

CEPHALOCHORDATA. *Amphioxus*, or Lancelet.

UROCHORDATA or Tunicata.—
3. *Salpa* type.
2. Ascidian type (sea-squirts.)
1. *Appendicularia* (larval type persistent.)

Surviving offshoots of ancestral Vertebrates.

HEMICHORDATA, surviving incipient vertebrates.
Balanoglossus and *Cephalodiscus.*

Nemertean affinities. Chætopod affinities. Arthropod affinities

Annelid Affinities. Dohrn, Semper, Beard, and others, maintain that Annelids have affinities with Vertebrates.

(1) Both Annelids and Vertebrates are segmented animals.
(2) The segmental nephridia of Annelids correspond to the primitive kidney-tubes of a Vertebrate embryo.
(3) The ventral nerve-cord of Annelids may be compared (in altered position) to the dorsal nerve-cord of Vertebrates. Both cords are bilateral, and it is likely enough that the tubular character of the spinal cord and brain is the necessary result of its mode of development, and without much morphological importance.
(4) Segmentally arranged ganglia about the appendages of some Chætopod worms may correspond to the branchial and lateral sense-organs of Ichthyopsida, and the ganglia associated with some of the nerves from the brain.
(5) The formation of the oral part of the pituitary body (see page 380) is suggestive of the way in which the mouth of Annelids is sometimes formed. Perhaps the pituitary body represents an old lost mouth and its ancient innervation.

To minor points such as the red blood, well-developed body-cavity, and slight internal skeleton of some Chætopods, little importance can be attached.

The absence of anything like gill-slits in Annelids remains as a difficulty, even if we grant that no emphasis is to be laid on the tubular nerve-cord of Vertebrates, and admit the possibility of an inversion bringing the ventral nerve-cord to the dorsal surface.

Nemertean affinities. Hubrecht and others have emphasised the affinities between Nemerteans and Vertebrates.

In Nemerteans :—

(1) The lateral nerve-cords sometimes approach one another ventrally, and in rare cases dorsally. An approximation dorsalwards and union on that surface would result in a double dorsal nerve-cord.
(2) The firm dorsal sheath of the proboscis may correspond to a notochord.
(3) The proboscis itself may correspond to the hypophysis or pituitary process characteristic of Vertebrate brains.
(4) Two ciliated slits on the head may correspond to a pair of gill-clefts.
(5) There is no segmentation, but the branches given off from the nerve-cords are sometimes serially arranged.

It must be noted, that those who support those theories, do not assert that any Nemertean or Annelid is in the direct line of Vertebrate ascent. They simply emphasise the demonstrable affinities. When these are thoroughly worked out, it will be possible to say what Invertebrate types are most nearly related to Vertebrates.

CHAPTER XVI.

BALANOGLOSSUS.

Class HEMICHORDATA.

THIS class has been established for the reception of the worm-like *Balanoglossus*, which has at least some remarkable approximations to Vertebrate structure. Along with it, *Cephalodiscus* should probably be ranked, and possibly the genus *Rhabdopleura* as well. It is possible that morphologists have made too much of the resemblances between these forms and Vertebrates, and too little of the differences, but the acceptance of the class Hemichordata may serve at least as an illustration of the absence of hard and fast lines in classification.

The Genus *Balanoglossus*.

The species which form this genus are worm-like marine animals, occurring in the English Channel, the Mediterranean, Chesapeake Bay, etc. They live in sand or mud, and exude mucus. In length, they vary from about an inch to over six inches, their colours are bright, their odours peculiar. They are very readily broken—in capture at any rate. The sexes are distinct, and the colours of the males are slightly different from those of the females. A species of *Balanoglossus* was described about the end of the 18th century by Delle Chiaje; Kowalevsky, who did so much to elucidate the nature of Ascidians and Amphioxus, also described this type; but it is only within the last few years that the researches of Bateson and others have led zoologists to appreciate its importance.

Before we give a connected account of the structure of *Balanoglossus*, its striking resemblances with Chordata, and especially with the lancelet-type, may be summarised from Bateson's memoir on the subject.

(1) *The dorsal nervous system* arises from the skin along the mid line of the back.

(2) *The notochord* arises as a supporting structure in the anterior end of the body by the constriction of a portion of endoderm from the gut.

(3) *The gill-slits* are formed as regular fusions and perforations of the body-wall and gut from before backwards. "Hence the three features which alone distinguish Chordata from other animals are present, and associated from an early period in development." Added to these, some minor features of Chordate anatomy are also represented by :—

(4) The origin of the mesoblast, from pouches of the primitive gut :

(5) The remarkable asymmetry of the anterior parts, *e.g.*, an anterior pouch cut off from the primitive gut, and opening externally, is paralleled in some measure in *Amphioxus* :

(6) The slight opercular fold, a growth of the "collar" over the gill-slits, perhaps comparable to the folds in *Amphioxus* :

(7) The excretory funnels opening into the slight atrial cavity thus formed.

On the other hand, it should be recognised, (*a*) that in addition to the dorsal nerve-cord, there is in *Balanoglossus* a ventral nerve-cord, a band round the pharynx, and a plexus beneath the skin ; (*b*) that the "notochord" of *Balanoglossus* lies ventral, not dorsal, to the main dorsal blood-vessel, and may be only an analogue, not a homologue, of the notochord of higher animals ; (*c*) that *Balanoglossus* is an unsegmented organism, whereas the higher forms are segmented, but it is possible that this difference is rather of physiological than of morphological importance. In short, the student must recognise that there is little certainty of knowledge in regard to the more detailed problems of organic relationship. Even the well-weighed opinions of the experts are to be accepted, as they are in most cases offered, as probabilities.

DIAGRAM XVIII.

BALANOGLOSSUS.

The figure *Bal.* shows the form of *B. kowalevskii*, *pr.* the proboscis, *col.* the collar, *g.* the region with gill-slits. (After Bateson.)

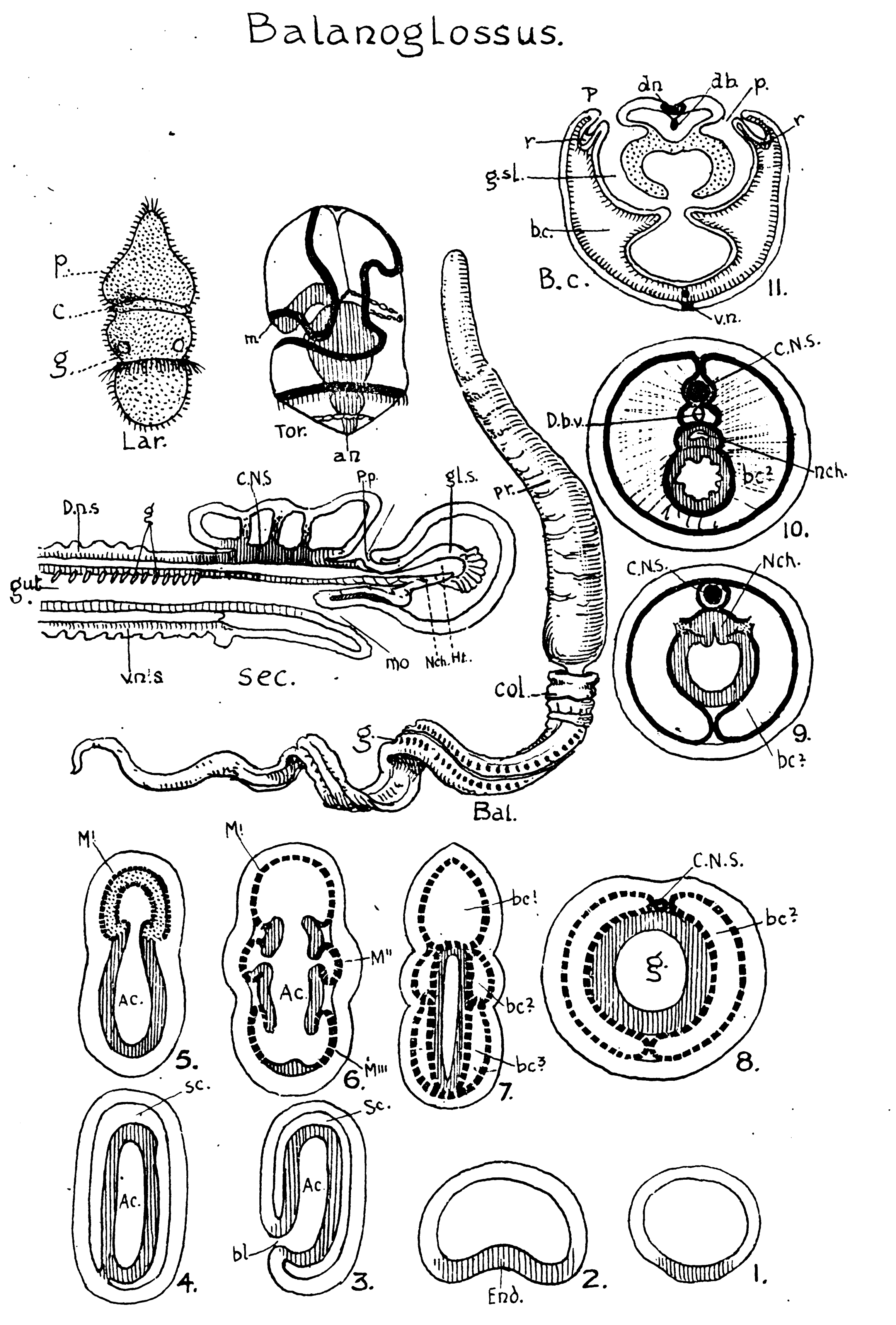
The figure *Sec.* is a longitudinal section of the anterior region, showing *P. p.* the proboscis pore, *mo.* the mouth, *Nch.* the notochord, *ht.* the heart, *gl. s.* the glandular sac, *c. n. s.* the central nervous system, *D. n. s.* the dorsal continuation of it, *v. n. s.* the ventral nerve, *g.* the gill-slits, and the gut. (After Bateson.)

Figure 11 shows a cross section in the region of the gill-slits, showing *p.* the pore of a gill-slit (*g. sl.*), *d. n.* the dorsal nerve, *d. b.* the dorsal blood-vessel, *r.* the reproductive organs, *b. c.* the body-cavity, *v. n.* the ventral nerve, and above that the ventral or nutritive region of the gut. (From Korschelt and Heider, after Spengel.)

Lar. represents a larva of *B. kowalevskii*, *p.* the proboscis, *c.* the collar, *g.* the openings of two gill-slits. (After Bateson.)

Tor. is a Tornaria larva, showing *m.* the mouth, *an.* the anus, and the ciliated band and ring as dark lines. (From Balfour, after Metschnikoff.)

Figs. 1–10 (after Bateson) illustrate the development :—1. a section of the blastosphere ; 2. the invagination which forms the gastrula, *end.* the endoderm ; 3 and 4. sections of a gastrula, *Ac.* the archenteron, *s. c.* the segmentation cavity ; 5–7 show the origin of the cœlome pouches—m', m'', m''', forming bc', bc^2, bc^3, the interrupted dark line is the mesoderm ; 8 is a cross section of the embryo, showing *g.* the gut, *c. n. s.* the central nervous system, bc^2, the lateral parts of the body-cavity ; in 9 and 10 the mesoderm is a continuous dark line, bc^2 the body-cavity, *Nch.* the notochord, *c. n. s.* the central nervous system, *D. b. v.* the dorsal blood-vessel.


Balanoglossus.
p
dn
db
p.
r
r
g.sl.
b.c.
B.c.
11.
v.n.
p.
c.
g.
Lar.
m
Tor.
an
C.N.S.
D.b.v.
nch.
bc²
10.
D.n.s
g
C.N.S
P.p.
gl.s.
pr.
gut
v.n.s
sec.
mo
Nch.
Ht.
C.N.S.
Nch.
9.
bc²
col.
g.
Bal.
M¹
M¹
Ac.
5.
M''
Ac.
M'''
6.
bc¹
bc²
bc³
7.
C.N.S.
bc²
g.
8.
sc.
Ac.
4.
Sc.
Ac.
bl
3.
End.
2.
1.

Description of *Balanoglossus.*

Form.—The worm-like body consists of a prominent pre-oral region or "proboscis," a firm "collar" behind the mouth, behind this a region with gill-slits, and finally, a long, soft, slightly coiled, ringed portion. It is to the tongue-like shape of the proboscis that the word *Balanoglossus* refers.

Skin.—The epidermis is ciliated, and exudes abundant mucus from unicellular glands. In *B. robinii* the mucus sets firmly. Some species are phosphorescent.

The Muscular System is best developed about the proboscis and collar, which are used in leisurely locomotion through the soft sand. There are external circular and internal longitudinal muscles. The fibres are unstriped.

The Nervous System includes a dorsal system, which is most definitely developed in the collar, but it extends along the dorsal surface. According to some, the nerve-cord in the collar has a central canal comparable to that of the spinal cord. But the dorsal nerve-cord in the collar is connected by a band round the pharynx with a ventral nerve. There is also a nervous plexus distributed beneath the skin. The adult has no special sense-organs, nor do we expect them in an animal which spends most of its life immersed in muddy sand. In the larvæ of some species there are two eye-spots.

Alimentary System.—The mouth lies ventrally between the proboscis and the collar, and is adapted for swallowing the sand moved about by the wriggling proboscis and by the collar. The pharynx is constricted into a dorsal and ventral region, of which the former is respiratory and connected with the exterior by many gill-slits, while the latter is nutritive, and conveys the food-particles onwards. This ventral region may be compared with the "ventral groove" in Tunicates, with the "hypobranchial" groove in the lancelet, with a similar region in the lamprey, and even with part of the thyroid gland in higher Vertebrates. Behind the region with gill-slits, the gut is digestive and absorptive, and bears throughout the anterior part of its course numerous glandular sacculations which can be discerned through the skin. The animal eats its way through the sand, and derives its food from the nutritive particles and small organisms therein contained.

The Skeletal System is represented by the "notochord," which lies in the proboscis, and arises like the notochord of indubitable Vertebrates from the dorsal wall of the gut. It is for the most part an anterior outgrowth of the gut. Beneath it there lies a "chitinous" rod, which divides into two in the collar. There is also a delicate "chitinous" skeleton about the gill-slits.

The Body-Cavity is somewhat complex, consisting of five distinct parts, all of which are lined by mesoderm, and arise as pouches from the primitive gut or archenteron. (*a*) There is first the unpaired cavity of the proboscis, which communicates with the exterior by a dorsal pore (or sometimes by two) at the base of the proboscis next the collar. From this cavity particles may pass out, but none have ever been seen going in. It is possible that a glandular structure, which lies in front

of the heart in the proboscis, may have some excretory significance, but it seems to be quite enclosed. (*b*) In the collar-region, there are two small paired cœlomic cavities, from which two funnels open to the exterior. Both these cavities and that of the proboscis tend to be obliterated by growth of connective tissue. (*c*) Two other cavities extend along the posterior region of the body, to some extent separated by the dorsal and ventral mesentery which moors the intestine. In these there is a body-cavity fluid with cells.

The Respiratory System consists of many pairs of ciliated gill-slits. They open dorsally behind the collar, and the most anterior are slightly overlapped by that structure. In development they begin as a pair, increase in number from in front backwards, and they go on increasing long after the adult structure has been attained. Water passes in by the mouth and out by the gill-slits, where it washes branches of the dorsal blood-vessel. Supporting the respiratory part of the gut there is a delicate skeletal framework.

The Vascular System includes a main dorsal blood-vessel lying *above* the notochord, an anterior dilatation which is sometimes called the "heart," a ventral vessel beneath the gut, and (in *B. minutus* at least) two lateral vessels which receive branches from gut and gills. The blood is said to flow forwards dorsally, backwards ventrally.

The Excretory System is slightly developed, but from the region overlapped by the collar two ciliated funnels open to the exterior, and we have already mentioned an enigmatical gland in the proboscis.

Reproductive System.—The sexes are separate. A number of simple paired genital organs lie in segmental order dorsally on each side of the body-cavity in or behind the region with gill-slits. But their distribution does not appear to be quite constant. They open by minute dorsal pores in the skin, or in the American species by rupture.

Development.—The eggs must be fertilised outside of the body. Segmentation is complete and approximately equal; a blastosphere or blastula results; this is invaginated in the normal fashion, and becomes a two-layered gastrula.

Soon, however, a remarkable difference between different species is manifest. The American species (*B. kowalevskii*) has a simpler development than the others, for it is without a remarkable larval form (Tornaria) which occurs in them. We shall take the simpler case first, though it is perhaps less primitive.

The blastopore or mouth of the gastrula narrows and closes; the external surface of the gastrula becomes ciliated; the endoderm lies as an independent closed sac within the ectoderm. Meanwhile the embryo has become or is becoming free from the thin egg-envelope, and begins to move about at the bottom in shallow water. It elongates and becomes more worm-like; there is an anterior tuft and a posterior ring of cilia; the primitive gut forms five cœlomic pouches; a mouth and an anus are formed, but there is no fore-gut nor hind-gut invagination; the regions of the body—the pre-oral proboscis, the collar, the gill-slit region with two apertures to begin with, and the posterior region—are defined at a very early stage.

The Tornaria larva of other species is at first bell-shaped, with a ventral mouth, curved gut, and posterior terminal anus, with external

ciliated bands somewhat like those of Echinoderm larvæ, with an apical sensory plate (like that of many Annelid larvæ), and two eye-spots upon this. The Tornaria becomes pelagic, acquires a proboscis, loses its special bands of cilia, and becomes diffusely ciliated, but has not yet a mouth or anus.

Johannes Müller ranked the Tornaria larva, whose adult form was not then known, beside the larvæ of Echinoderms. The ciliated bands of the Tornaria resemble those of Echinoderm larvæ, but this is only a superficial characteristic. The anterior pouch which forms the cavity of the proboscis and communicates with the exterior has also been compared with the beginning of the water-vascular system in Echinoderms, and it is true that in both several independent cœlome pouches grow out from the primitive gut. But almost as good or as bad a case might be made of the resemblances between a Tornaria and an Annelid trochosphere; and probably a better case can be made of the likeness between certain features in the development of *Balanoglossus* and that of the lancelet.

Among the species of *Balanoglossus* are *B. minutus* (Naples), *B. salmoneus* (Brittany), *B. robinii* (Brittany), *B. koehleri* (English Channel), *B. brooksii* (North America), and *B. kowalevskii* (Chesapeake Bay). The last differs from the others in having a relatively long proboscis, no hepatic sacculations, a simpler branchial skeleton, very short collar funnels, a larger backward fold of the collar, and a simpler development without a Tornaria larva.

CEPHALODISCUS.

This is a unique genus, having marked affinities with *Balanoglossus*, and is perhaps another prophecy of the more definitely Vertebrate types.

A single species (*Cephalodiscus dodecalophus*) was dredged by the *Challenger* in the Magellan Straits. Large numbers of minute individuals live in a branching, brownish, seaweed-like investment, which may measure 9 inches by 6 inches. The organism was monographed as a divergent Polyzoon by M'Intosh, but the researches of Harmer forcibly suggest that *Cephalodiscus* is allied to *Balanoglossus*.

Cephalodiscus is said to agree with *Balanoglossus* in the following characters :—

(1) Division of the body into proboscis, collar, and trunk; this being specially obvious in the young bud.

(2) An unpaired body-cavity in the proboscis, and paired cavities in collar and trunk.

(3) Proboscis-pores opening into body-cavity of pre-oral lobe.
(4) Collar-pores opening into collar-cavity, overhung by an operculum developed from the collar.
(5) The presence of gill-slits.
(6) " Existence of a notochord as a diverticulum of the alimentary canal, growing forwards into the proboscis-stalk."
(7) " Dorsal central nervous system, most richly developed in the collar, but extending on to the proboscis."

These affinities, and the last three characteristics in particular, perhaps justify the position of *Cephalodiscus* beside *Balanoglossus*, as a second genus of Hemichordata.

Appendix to Hemichordata.

RHABDOPLEURA.

A unique genus found at considerable depths in the North Sea. It forms branching colonies attached to foreign objects. The head of each individual bears a pair of lateral arms with ciliated tentacles. Between the bases of the arms is a ciliated mobile disc overhanging the mouth. This disc seems to secrete a tube which surrounds the animal, and it also helps the animal to move within its tube. The arms and the tentacles have a skeletal support, and there is an axial skeleton in the body. The gut has a U-shaped curvature, as in Polyzoa. Neither nervous system nor nephridia are known. The affinities of *Rhabdopleura* are uncertain, perhaps it is related to Polyzoa, perhaps to *Cephalodiscus*.

CHAPTER XVII.

TUNICATA OR UROCHORDATA.

THE Tunicates, including the common Ascidians or sea-squirts, are degenerate Vertebrates. The young forms have a dorsal nervous system, an underlying notochord in the tail region, gill-slits opening to the exterior, an eye developed from the brain. But in most cases this promise is unfulfilled, the larvæ settle down and lose tail and notochord, nerve-cord and eye, becoming quaintly deformed.

In many adults the shape of the body is like that of a bent wine-sack with two apertures. Through one the water is drawn in, bearing food-particles with it; through the other it is swept out. Passing in by the mouth the water enters a large respiratory pharynx whose walls are perforated by numerous ciliated slits; through these it passes into a surrounding (atrial or peribranchial) chamber, and thence out by the exhalent aperture.

The cuticular tunic of the adult seems to contain a carbohydrate nearly allied to, if not identical with cellulose, and also some proteid substance. The nervous system is reduced to a single ganglion, situated between the mouth and the exhalent aperture. The heart is a simple ventral tube, which drives the blood first in one direction then in the other. There are no nephridia. The animals are hermaphrodite.

Many sea-squirts (so-called from the force with which water is sometimes driven from the exhalent aperture) are common on or near the coasts of all seas. They are usually attached to stones or shells, or to the muddy bottom. Few individuals measure more than three or four inches in length, and most of them less. They live on minute organisms which are carried in by the water-currents. Many form buds from their basal parts, and great clusters thus arise, *e.g.*,

in the common *Ascidia*. In others, budding has resulted not in mere clusters, but in composite organisms, *e.g.*, *Botryllus*. Furthermore, the unitedness of the colony may be very thorough, as in the fire-flame *Pyrosoma*, which, though composed of numerous individuals, swims as one creature.

Very different from the above, none of which are very far removed from the common Ascidian type, are the free-swimming genera *Salpa* and *Doliolum*. They have a complex structure, and exhibit alternation of generations.

Finally, there are a few genera which retain the larval characteristics. Of these, *Appendicularia* is the simplest type.

(I.)—*The Appendicularia Type.*

Sub-Class Larvacea (synonyms Copelata, Perennichordata).

Brief description of Appendicularia.—It is instructive to begin with this genus, for it retains the larval characteristics. The animals are free-swimming and minute. Their shape is somewhat like that of larval Ascidians. A long locomotor tail projects ventrally beneath the small oval body. Epidermic cells near the mouth secrete a slimy but consistent test, or "house," which is abandoned and formed anew from time to time. The tail with its supporting notochord shows hints of segmentation or vertebration. The nervous system consists of a lobed ganglionic mass above the mouth, of a nerve-cord connecting this with a second ganglion at the beginning of the tail, along which (rather to one side) the nerve-cord is continued with more ganglia. Both cord and ganglia are said to include an axial canal, and nerves issue from the ganglia. The cerebral ganglionic mass has in connection with it a pigment spot (optic?), an otocyst (auditory?), and an inferior tubular process communicating with the pharynx. There are only two gill-slits. The mouth is almost at the anterior end; the food-canal ends at the root of the tail. The heart is ventral, without definite vessels. The hermaphrodite reproductive organs lie posteriorly and are ductless; there is a special dorsal brood-pouch.

Genera.—*Appendicularia. Oikopleura. Fritillaria. Kowalevskia.*

(II.)—*Ascidia Type.*

Sub-Class Ascidiacea.

Description of a simple Ascidian.—To common sea-squirts like *Ascidia*, *Phallusia*, *Ciona*, the following description will apply.

The shape is more or less that of a double-mouthed flask; mouth and exhalent aperture lie near one another.

The epidermis secretes a cuticle or tunic, which in part

consists of cellulose, or some analogous carbohydrate. It is interesting to find this product—characteristic of plants—in the very passive cuticle of a very passive animal. But though the tunic is at first truly a cuticle, and without cells, these may migrate into it, and even blood-vessels may be formed.

The *Muscular System* forms beneath the epidermis a netted sheath of unstriped fibres, and special sphincters surround the apertures.

The *Nervous System*, comparable in the larva to a spinal cord and slight brain, is represented in the adult by a ganglionic mass lying between the two apertures, and giving off a few nerves.

Sensory Structures.—Beneath the ganglion lies a small (sub-neural) gland, from which a ciliated duct opens into the pharynx. It is possible that this corresponds to the pituitary body (see page 380), possible that it may be excretory, possible also that it may have some sensory water-testing function. Some of the Ascidian larvæ have an otocyst and an eye-like pigment spot, both in close connection with the brain, but these are not retained in the adults of this type.

But some or all of the following structures, which will be described below, are in all likelihood sensory—pigment spots between the lobes of the apertures, tentacle-like processes beneath the mouth, and other processes (languets) on the dorsal wall of the pharynx.

Alimentary System.—The mouth is the uppermost aperture, slightly puckered, often with pigment spots between its lobes. It leads into a large respiratory pharynx, near the beginning of which is a circle of downward pointing tentacle-like processes. Water, bearing minute algæ and animals, is drawn in by the action of cilia, which border numberless small slits in the wall of the pharynx. The food-particles are glued together by a mucous secretion, and swept backwards to the digestive and intestinal region of the gut which begins at the base of the pharynx, while the water passes through the slits of the pharynx walls into a surrounding peribranchial chamber, and thence out by the exhalent orifice.

On the internal ventral surface of the pharynx, *i.e.*, on the wall opposite that above which the ganglion lies, there is a longitudinal groove or gutter called the endostyle. It is ciliated and in part glandular, and from it some observers

DIAGRAM XIX.

TUNICATA.

Figs. *A*, *B*, and *C* (after Ray Lankester) illustrate how a larval Ascidian degenerates into the adult form.

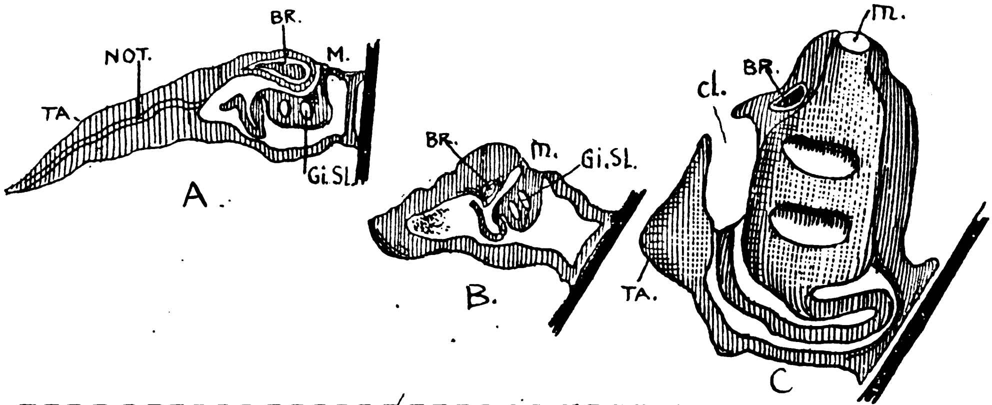
Ta., tail; *Not.*, notochord; *Br.*, brain; *M.*, mouth; *Gi.-sl.*, gill-slits; *Cl.*, cloacal chamber.

The figure of a simple *Ascidian* represents an animal opened on the right side, but the gut and reproductive organ (*rep.*) on the left are supposed to be shining through. The mouth (*m.*), the latticed pharynx, with dorsal ridge and ventral groove (*v. g.*), the coiled gut, the cloaca (*cl.*), the dorsal ganglion (*gn.*), the ventral heart (*h.*) are indicated. Around the body is the tunic.

The section to the right shows the external tunic, beneath which is the body-wall, within which, surrounding the pharynx (*ph.*), and opening into the cloacal chamber, is the peribranchial cavity (*p. b. c.*).

Beneath, some stages in the development are shown (after Hæckel). *A*, the ovum; *B*, the first four cells; *C*, a section of the gastrula; *D*, a young embryo, showing gut (*G*), neural canal (*n. c.*), and notochord (*not.*).

Tunicata.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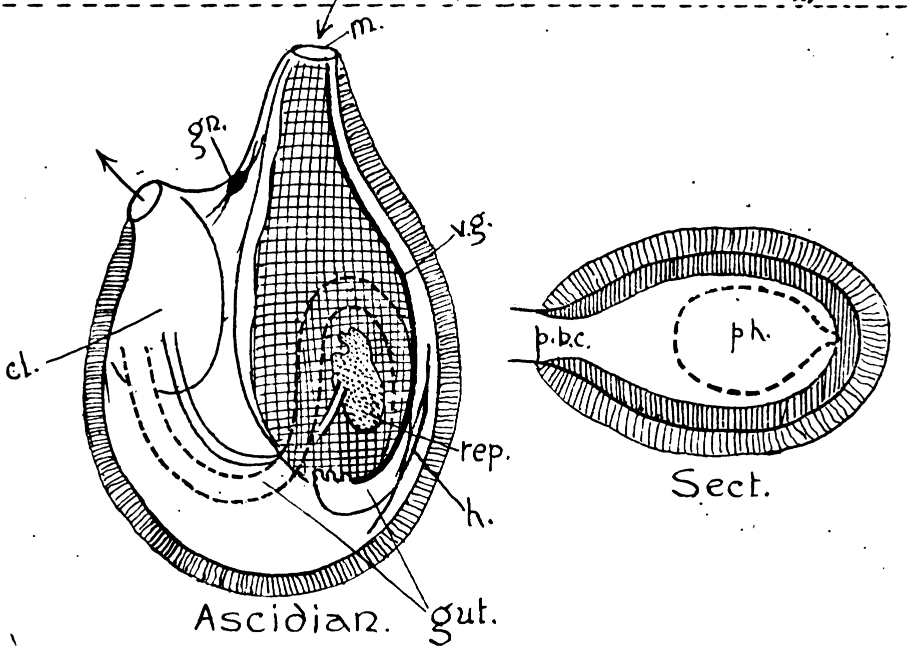
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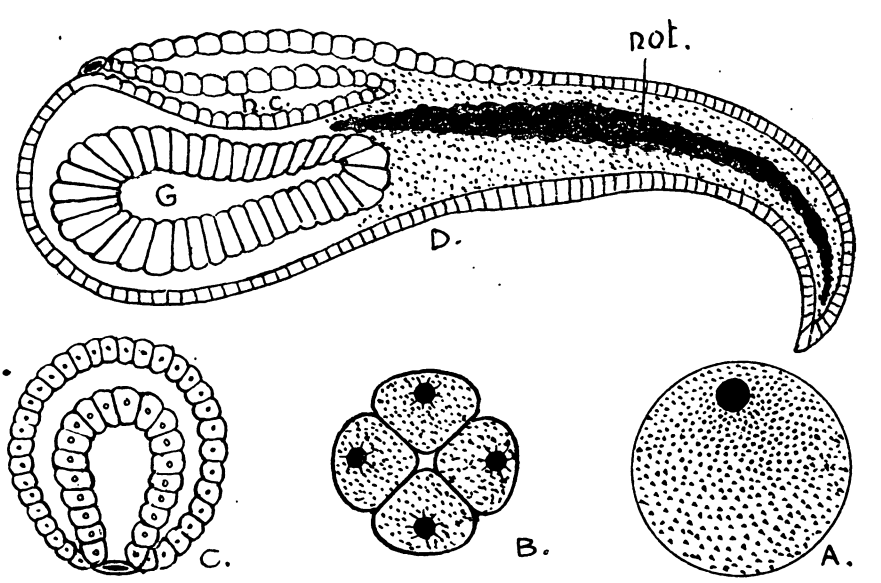
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say that mucus is wafted forwards to form a sort of web near the mouth, from which entangled food-particles are wafted backwards, along the dorsal wall of the pharynx to the beginning of the digestive gut. On the dorsal wall there is a ciliated fold—or dorsal lamina—which is sometimes broken up into tongue-like processes or languets. On the other hand, Herdman notices that comparatively few of the endostyle cells are glandular, that much of the mucus seems to be secreted elsewhere, perhaps even from the sub-neural gland, that the food-particles are in all likelihood swept backwards both ventrally and dorsally. As to the morphological importance of the ventral groove or endostyle, it may be compared with the ventral portion of the respiratory pharynx in *Balanoglossus*, with the "hypobranchial groove" to be afterwards described in *Amphioxus*, and even with the thyroid gland of higher Vertebrates, for that in part arises as a constriction from the ventral wall of the pharynx.

At the base of the pharynx, lies the opening of the digestive and intestinal part of the gut. This is continued downwards, and on to the other side of the animal where an S-shaped curve is often described by the intestine. With this part of the gut, a glandular mass is often associated, and the wall is folded inwards as it is in the earthworm. Finally, the intestine ends in a cloacal chamber near the exhalent aperture.

Respiratory System.—Let us now trace the course of the water which was drawn in at the inhalent aperture. Bereft of some of its food-particles, it passes through the numberless ciliated slits in the walls of the pharynx, washing the blood-vessels exposed on these walls. It passes into a peri-branchial chamber which ensheathes the pharynx, and this opens out by the exhalent aperture. This peribranchial chamber is in part at least lined by ectoderm, for it is formed from a modification of the two gill-slits which the larva possesses, and these result from two invaginations of ectoderm which meet two outgrowths of the gut. The slits on the pharynx can hardly be compared with ordinary gill-slits, though they serve the same purpose; they are secondary structures which replace the two primary gill-slits of the larva, and communicate only indirectly with the exterior, namely, through the peribranchial chamber.

Vascular System.—The tubular heart is a dilatation of a ventral vessel, and lies in a pericardial space—part of the body-cavity—to the side of the lower end of the pharynx. For a number of beats it drives the blood upwards, and then the direction is reversed. The same reversal occurs in *Phoronis*. Transverse and longitudinal blood-vessels (they cannot be called veins or arteries) lie on the walls of the pharynx between the slits.

According to Herdman, the ventro-dorsal contractions occasion the following circulation. From the pharynx or branchial sac, the blood collects in a branchio-cardiac vessel, receives contributions from the tunic, enters the heart, is propelled into cardio-visceral vessels which lead it to the tunic, the viscera, etc., whence it is gathered in viscero-branchial vessels and diffused on the branchial sac. When the dorso-ventral contractions begin, all this is reversed. The blood seems very colourless, but there are usually a few pigmented corpuscles in it.

Excretory System.—In the loop of the intestine, there lies a mass of clear vesicles containing uric acid and other waste-products. This seems to be a renal organ, in which Bacteria are usually found, but there is no duct. Perhaps the sub-neural gland has some renal function, as has also been suggested in regard to the proboscis gland of *Balanoglossus*.

Reproductive System.—Tunicates are hermaphrodite. The simple reproductive organs are embraced by the loop of the intestine. The ovary is the larger and contains a cavity into which the ova are set free, and from which they pass outwards along an oviduct which opens into the cloacal chamber. The testis surrounds the ovary, and is mature at a different time (dichogamy); its duct runs alongside the oviduct. But in many cases (where the reproductive organs are near the cloaca) there are no ducts. The ova are surrounded by follicular cells; they seem to be fertilised within the body.

Development.—In 1866, Kowalevsky traced the development of *Amphioxus*; he showed moreover that its earlier stages were exactly paralleled by those of an Ascidian.

The fertilised ovum divides completely. The result of segmentation is a blastosphere. This undergoes regular segmentation, and becomes a two-layered gastrula.

Along the dorsal median line of this gastrula, the ectoderm

cells form a groove, the medullary groove, the sides of which arch together and form a canal—the medullary canal. Thus the central nervous system is established. The mesoderm seems to arise from outgrowths of the primitive gut or archenteron; the notochord is formed along the dorsal wall of the same, but grows in the tail region only; two gill-clefts arise from invaginations of ectoderm which meet outgrowths of gut.

The tadpole-like Ascidian larva enjoys for a brief space a free life. It uses the tail as a swimming organ. But whether it over-fatigues itself, or whether it is under the spell of some constitutional tendency, it soon settles down to sedentary life. It fixes itself by papillæ on its head; the tail shrivels and is absorbed; the nerve-cord and notochord disappear; the primary gill-slits are lost in forming the peri-branchial chamber, and the secondary slits replace them; the whole animal undergoes a metamorphosis, which is one of the most signal instances of degeneration.

(III.) *Salpa and Doliolum Type.*

Sub-Class Thaliacea.

These animals are persistently locomotor. They swim in the open sea, like barrels with mouth at one end, exhalent aperture at the other. The cuticle is very thin, as we would expect in animals so active. The muscles form hoops around the body.

These forms exhibit alternation of generations. In *Salpa* an asexual generation or "nurse" forms a ventral posterior "stolon." On this, buds are formed which are set free as a chain of sexual *Salpæ*, the links or individuals of which eventually separate. In *Doliolum*, a small stolon forms a number of primitive buds, which creep over the parent and multiply. They form a lateral series of nutritive individuals, and a median series whose individuals are set free as asexual "foster-mothers." These carry with them some primitive buds, which divide into secondary buds, which become sexual. Their ova develop into "nurses."

Classification of Tunicata.

1. Larvacea. *Appendicularia*, *Oikopleura*, *Fritillaria*, *Kowalevskia*.
2. Ascidiacea. (*a*) Simple. *Ascidia*, *Phallusia*, *Ciona*.
   (*b*) Composite. *Botryllus*, *Polyclinum*.
   (*c*) Social. *Pyrosoma*, the phosphorescent fire-flame.
3. Thaliacea. *Salpa*, *Doliolum*.

CHAPTER XVIII.

CLASS CEPHALOCHORDATA. AMPHIOXUS.

(SYN. LEPTOCARDII, ACRANIA.)

THE lancelet (*Amphioxus*) is found near the coast in most warm and temperate seas. It is pointed at both ends as its names suggest, it rarely measures two inches in length. It has a faint flesh colour, and is translucent.

The lancelets are fond of lying in the sand in water about two fathoms deep, all covered except the fringed aperture of the mouth, through which diatoms and other small organisms are sucked in. In the evening especially, they sometimes start up and swim about, bending the body in wriggling motion. The young swim about more than the adults.

Characteristics.—There is no doubt that *Amphioxus* is far removed from the type of Fishes. It has no limbs, no skull, no jaws, no well-defined brain, no sympathetic nervous system, no ear, no heart, no spleen, no kidneys, no reproductive ducts. The notochord persists unsegmented, surrounded by a continuous sheath. A median fin extends along the back, around the tail, and for some distance along the ventral surface. But in its dorsal nervous system, notochord, and gill-slits, *Amphioxus* exhibits the essential Vertebrate characters. There is but one genus with about half a dozen species, of which *A. lanceolatus* is best known.

Description of *Amphioxus lanceolatus*.

Form.—The body is thin and sharp at each end. The muscles are disposed in sixty-two segments or myotomes.

Three apertures are evident; (*a*) the mouth fringed by little tentacle-like processes, and overarched by a pre-oral hood; (*b*) about two-thirds of the animal's length from the head the atriopore or branchial pore (in myotome thirty-six), through which the water which enters by the mouth and washes the gill-slits passes out; (*c*) the anus nearer the posterior end of the body. On each side of the region between the mouth and the branchial pore, are two folds or epipleura, which have covered over the originally external apertures of the gill-slits, and have formed an atrial or branchial chamber. This region in front of the atrial pore is marked externally by its flat ventral surface, which is fringed on each side by a fin-like "metapleural" fold. These are due to the epipleural flaps mentioned above. As will be afterwards seen, the animal is less perfectly symmetrical than it at first sight appears, and perhaps this is due to its habit of frequently lying on one side.

Skin.—The epidermis is a single layer of cells, some of which, with projecting tips and basal connections with nerve-fibres, are sensory. Very similar cells occur along definite lines in fishes, and also on young tadpoles. Beneath the epidermis lies a clear cutis without nuclei. Beneath this are fine tubes which seem to be derived from the body-cavity, and unite in a longitudinal canal running along each metapleural fold. The median fin extends along the back, around the tail, and between the tail and the atriopore. The dorsal and the ventral fins are supported by what may be called "fin-rays"; of these there are 250 along the back.

Skeleton.—This is very slightly developed. There is not only no bone, but the supporting material is not even definitely cartilaginous.

(*a*) The elastic notochord runs from tip to tip. It is unsegmented, and is surrounded by a continuous sheath of connective tissue.

(*b*) The respiratory pharynx is supported by a system of horny (?) rods, which lie between the numerous gill-slits. There is also a paired longitudinal plate along the mid-ventral groove of the pharynx.

(*c*) The mouth is embraced by two curved bars, each segmented into about a dozen pieces, which bear filaments supporting the tentacles.

(*d*) The "fin-rays," the sheath which extends from the notochord around the nerve-cord, the septa of connective tissue between the muscle-segments may also be included. To the latter the < shaped markings of the animal are due.

Muscular System.—The animal swims by wriggling its body laterally. This is effected by the lateral muscles, which are divided into muscle-segments, myotomes, or myomeres. In these the muscle-fibres run longitudinally, but there is a transverse set on the ventral surface between the mouth and the atriopore. They help to drive the water out of the atrial cavity. Other muscles occur about the mouth, etc. Nearly all the fibres are striated.

Nervous System.—The spinal cord, lying within a continuation of the notochord-sheath, extends along the mid-dorsal line.

From the cord two independent sets of nerves arise, dorsal nerves corresponding to the segments, ventral nerves much more numerous. These two sets are comparable to the single-rooted, sensory, dorsal nerves, and the many-rooted, motor, ventral nerves of higher Vertebrates; but in *Amphioxus* the two sets do not unite. Moreover, the dorsal nerves pass to the muscles as well as to the skin, and they have no ganglia. Nor are there any sympathetic ganglia.

There is no anterior swelling or brain. It seems, however, that there is some histological distinctiveness about the anterior region, and that the first five pairs of sensory nerves are to be regarded as cerebral.

With the anterior region, where a brain ought to be, the following structures are connected :—

(*a*) On the left side, there is an olfactory (?) ciliated pit, connected by a tube with the canal of the nerve-cord. It may be that this is a "neuropore" or aperture left when the folds of the medullary groove closed to form a canal.

(*b*) There is also a pigment-spot, sometimes called an eye-spot, at the very end of the nerve-cord.

(*c*) A sac, apparently containing sensitive cells, opens on the roof of the mouth. It may be a tasting or smelling organ. It arises from the left of two pouches, which grow out anteriorly from the front of the gut or archenteron of the embryo.

It is likely that the most important sensory structures are the sensitive cells scattered in the epidermis.

Alimentary System.—The mouth is usually exposed when the animal is lying in the sand. It is fringed by about thirty ciliated tentacles or cirri, which are supported by filaments from the segments of the mouth bars.

Within the mouth lies a membranous flap or velum, separating the cavity of the mouth from that of the pharynx, but perforated by an aperture, through which mouth and pharynx communicate. The aperture of the velum seems to represent the mouth of the larva.

The pharynx, like that of Tunicates, and indeed of Fishes also, is modified for respiration. Its walls are perforated by numerous gill-slits on each side, and between these lie supporting bars or arches, alternately split and unsplit. The internal surface of the pharynx, like that of the mouth, is richly ciliated.

Along the mid-dorsal and mid-ventral lines there are grooves, hyper- and hypo-branchial respectively. The latter is comparable to the endostyle of Ascidians.

The intestinal region of the gut is straight and simple, except that near its commencement, a pouch-like "liver" arises and extends forward on the right side of the pharynx. The anus lies rather to the right side.

Body-Cavity.—This arises as a paired and subsequently transversely divided pouch from the gut or archenteron of the embryo. Its extent is not very easily appreciated in the adult, especially in the region of the atrial cavity.

Posteriorly the body-cavity is the wide space between the intestine and the body walls. In the anterior region it is reduced to small canals, which lie above and by the side of the pharynx, and within the metapleural folds or lateral fins. Besides the main canals, there are others which replace the lymphatic system of higher animals. The cavities contain coagulable fluid, and are in some regions continuous with the blood-vessels.

Respiratory System.—The water which enters the mouth and is swept down the pharynx passes out by the gill-slits. In the embryo it regains the exterior directly; in the adult it is received into an atrial chamber, which opens by the single atriopore. This atrial chamber is formed by the

DIAGRAM XX.

AMPHIOXUS.

At the top is a figure of the entire animal (after Ray Lankester), showing the notochord (*notoch.*), the tentacles (*tent.*) around the mouth, the reproductive organs (*rep.*), the myotomes, atriopore, anus, and fin-rays.

Below is a cross section (after Ray Lankester) showing the spinal cord (*sp. c.*), the notochord (*notoch.*), the pharynx (*phar.*) with dorsal groove (*d. g.*), ventral groove (*v. g.*), and perforated walls, the "liver" cæcum (*cæc.*), the atrium, the reproductive organs (*rep.*), the atrio-cœlomic canals, the lymph space (*l. sp.*) in the metapleural folds.

Figs 1–8 (after Hatschek) illustrate the development.

1. A ripe ovum with extruded polar globule.

2. The stage with four cells, seen from above.

3. The blastosphere, showing slightly larger cells at the inferior pole.

4, 5. Sections of the blastosphere.

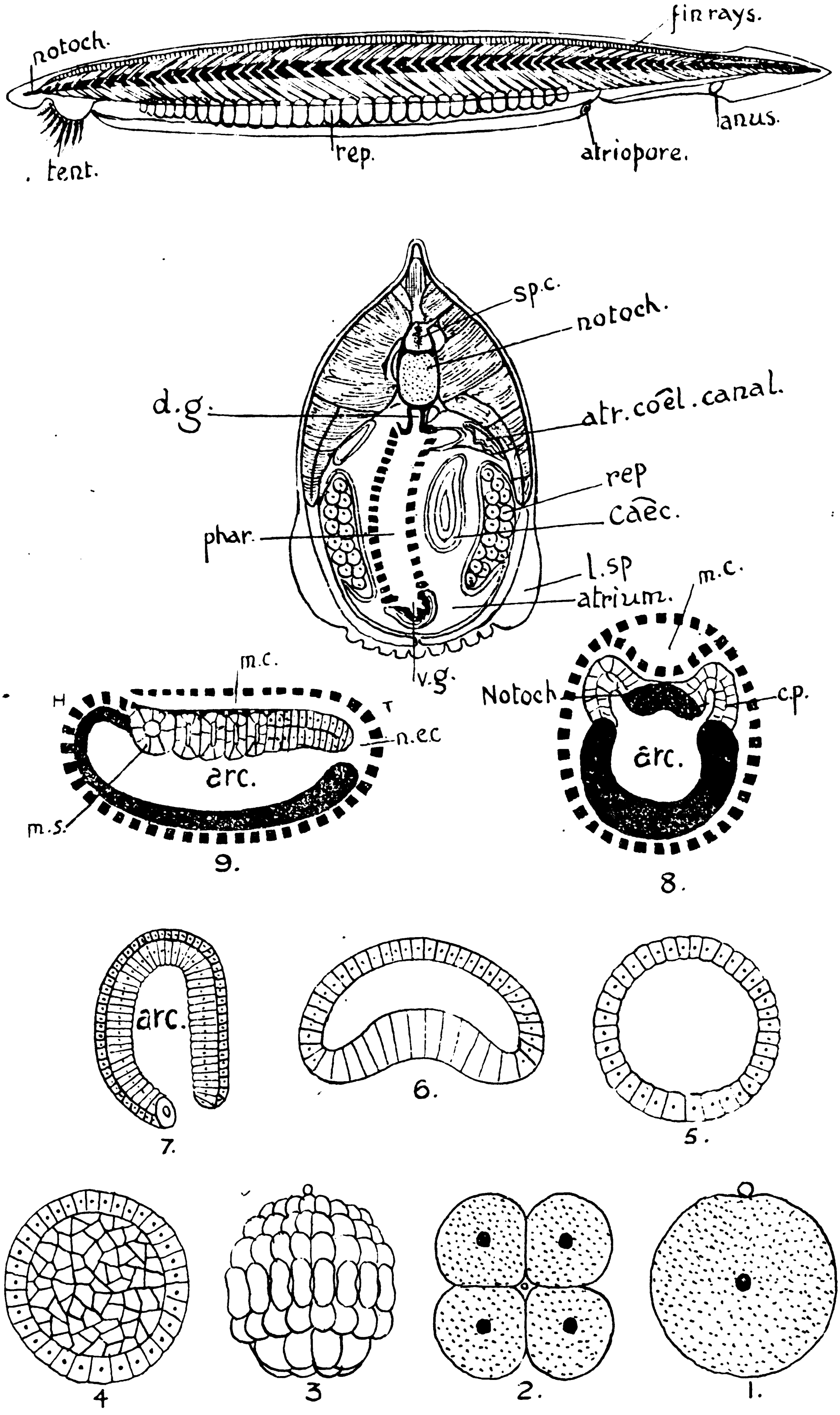
6. Invagination.

7. The gastrula ; *arc.* the archenteron.

8. A cross section of the embryo, the ectoderm is the interrupted dark line, the endoderm is solid black, the mesoderm is light. The medullary or neural canal (*m. c.*), the archenteron (*arc.*), the cœlomic pouches (*c. p.*), the incipient notochord (*notoch.*), are shown.

9. A longitudinal section of the embryo, the head end (*H.*), the tail end (*T.*), the medullary or neural canal (*m. c.*), the archenteron (*arc.*), the neurenteric canal (*n. c. c.*), the mesodermic segments (*m. s.*), are indicated.

Amphioxus.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growth of two lateral folds or epipleura, which grow as flaps over the gill-slits, and join one another ventrally. The water-currents are kept up by the action of cilia, and by the movements of the transverse ventral muscles.

The gill-slits gradually become more numerous as the animal grows older, and in the adult there are more than a hundred. The unsplit or secondary rods supporting the pharynx seem to divide the halves of originally single gill-slits.

Circulatory System.—The blood is colourless, with a few amœboid cells. There is no definite heart, but the vessels are said to be at several places contractile. Vessels from the body and from the liver unite in a ventral vein ("cardiac aorta"), lying beneath the pharynx. Thence the blood is perhaps driven along the primary branchial rods between the gill-slits (in "aortic arches"), and may flow into two dorsal vessels ("dorsal aortæ") which unite behind the pharynx. The most anterior aortic arch on the right side is much larger than the rest, and sends branches to the head. The blood-vessels, which presumably take blood from the intestine to the liver, may be called portal veins, those which presumably lead blood from the liver and unite to form the ventral vein may be called hepatic veins. The portal vein and the cardiac aorta are said to be specially contractile. But while the distribution of the vessels is well known, we are ignorant in regard to the flow of the blood.

Excretory System.—In regard to this there is uncertainty. At most there are only traces of nephridia.

(*a*) Hatschek discovered in the larva a nephridial tube near the mouth, but this does not persist in the full-grown adult. "It extends on the left side from the margin of the mouth to close behind the velum."

(*b*) Ray Lankester discovered a pair of short pigmented funnel-tubes which lie in the twenty-seventh segment, and place the cœlomic canals of the epipleural folds in communication with the atrial cavity. They may be compared with the pores which open from the collar region of *Balanoglossus*, with the abdominal pores of higher Vertebrates, and with nephridia.

Reproductive System.—The sexes are separate and similar to one another. The reproductive organs are very simple and ductless. They form 26 pairs of horse-shoe-shaped

sacs, lying along the inner wall of the atrial cavity in segments 10–36 on each side. In reality they lie in little compartments of the cœlome.

In the mature female the ovaries are large and conspicuous; the ova burst into the atrial cavity, whence they pass into the pharynx and out by the mouth, or more directly by the atrial pore.

The testes are like the ovaries; the spermatozoa burst into the atrial cavity, and pass out by the atrial pore. It is likely that the eggs are fertilised in the water.

Development.—The fertilised ovum segments completely and equally; the resulting blastosphere is invaginated to form a gastrula.

Along the mid-dorsal line of the gastrula, the epiblast cells form a medullary groove, which becomes a medullary canal, and thus the central nervous system is formed.

The cavity of the gastrula—the archenteron—becomes the gut of the adult.

The notochord arises along the mid-dorsal line of the archenteron.

From the archenteron a cœlome pouch grows out on each side. Each is divided from before backwards into a segmental series of sacs. The cavities of these sacs form the body-cavity; their walls the mesoblast.

There are several anterior pouches. Two grow forward, one on each side of the notochord. These form the most anterior part of the body-cavity. But there is also an unpaired sac which extends forward, and divides into two. Its right half seems to have no special history, but the left forms the organ of smell or taste which we spoke of as opening on the roof of the mouth.

The larva is ciliated during the early part of its life, and is much more active than the adult.

CHAPTER XIX.

STRUCTURE AND DEVELOPMENT OF VERTEBRATES.

To avoid the tiresome repetition of explanatory statements, or burdening the description of fish or frog with general questions of morphology, I have here summarised some of the more important facts.

As prominence has already been given to the essential characteristics,—the dorsal and tubular nervous system, the notochord, the gill-slits, the segments, etc.,—we shall discuss the various systems in their conventional order.

Skin.—This includes—

(*a*) The epidermis, usually in several layers, "horny," "mucous," etc., all derived from the ectoderm, or epiblast of the embryo.

(*b*) The dermis, cutis, corium, or under-skin, derived from the mesoderm or mesoblast of the embryo.

From the epidermis are derived feathers, hairs, and some kinds of scales; the dermis helps in nourishing them. From the dermis are derived the bony shields of armadilloes and a few related mammals, the bony scutes of crocodiles and some other reptiles, and the scales of most bony (Teleostean) fishes. Teeth and the skin teeth of gristly fishes are due to both layers.

Muscular System.—In the lancelet, in Fishes, and in the tail region of the higher Vertebrates, the muscles are disposed in segments or myomeres. Above Fishes, the muscles of the trunk no longer show in the adult any such arrangement.

The muscles of the body-wall are derived from primitive muscle-plates, and these from the original segments into which the mesoblast of the embryo is divided. "From the same source the muscles of the limbs are derived in Elasmo-

branchs, and perhaps other Fishes, as also in Amphibians and Lacertilians, but in higher Vertebrates they arise independently." Most of the visceral muscles consist of unstriped fibres, but those of the outer parts and of the heart show the usual striped structure.

Skeletal System.—Apart from the exoskeleton of skin teeth, scutes, shields, etc., the skeleton consists of the following parts—

(*a*) Axial Skeleton.	The skull and its associated "arches." The backbone and associated ribs. (The notochord is transitory except in the simplest Vertebrates.)
(*b*) Appendicular Skeleton.	Fore-limbs, and pectoral girdle. Hind limbs, and pelvic girdle.

Skull.—In very early stages the cavity in which the brain lies is surrounded by a membranous sheath comparable to that which ensheathes the notochord. The elements of the skull are as follows :—

(*a*) The foundation is formed from two pairs of plates—posterior parachordals and anterior trabeculæ—which lie beside and in front of the notochord. These are extended upwards by a further formation of cartilage, the result of which is a cartilaginous brain-box or chondrocranium. The end of the notochord may also help a little.

(*b*) The gristly brain-box is added to laterally by a pair of cartilaginous nasal capsules in front, and a similar pair of auditory capsules behind.

(*c*) About the mouth there are some lip or labial cartilages, but much more important is a series of arches (never more than eight) which loop round the pharynx on each side, running between the primitive gill-clefts. The two which lie furthest forward—the mandibular and the hyoid arches—are of great moment in the development of the skull; the others form supports for the region of the pharynx, which in Fishes and at least all young Amphibians bears open gill-slits. In the Elasmobranch fishes, the mandibular and hyoid arches do not form any direct part of the cartilaginous brain-case, but in the Teleosteans and thence onwards they, or the bones

which replace them, contribute directly to the building up of the skull.

The mandibular arch in Elasmobranchs and frogs divides into a lower portion—Meckel's cartilage—which forms the lower jaw or its basis, while from the upper portion a bud grows forward—the palato-pterygo-quadrate cartilage, which forms the upper jaw in shark and skate, and has a closer union with the skull in the frog. In higher Vertebrates, the lower portion of the mandibular always forms the basis of the lower jaw, a quadrate element is segmented off from the upper part, but the palato-pterygoid part seems to arise more independently. The hyoid arch also divides into a lower portion, the hyoid proper, and an upper portion, the hyo-mandibular, which may connect the jaws with the skull, or from Amphibians onwards may be more remarkably displaced and modified as a columella or stapes connected with the ear. We adhere to the old interpretation according to which the mandibular and hyoid form two arches; even if Dohrn's theory that they are equivalent to four be accepted, the general fact remains that certain arches aid in the development of the skull.

(*d*) When a bone develops in direct relation to a pre-existent cartilage which it replaces, it is often called a primary or "cartilage" bone. Thus many regions of the brain-box which are cartilaginous in the embryo are replaced by bones in the adult.

But there are other bones which develop independently of pre-existent cartilage. They invest the cartilaginous brain box on the roof, on the floor (*i.e.*, in the mouth cavity), and on the sides. These are often called secondary or "membrane" bones, and they seem to correspond to dermal ossifications such as the bony parts of the skin-teeth of Elasmobranchs, or to the bony plates of Ganoids. It is likely that the roofing bones of the skull originated from plates like those which form the dermal armour of sturgeons. In structure, be it understood, a cartilage bone is not distinguishable from a membrane bone; the distinction refers to the development.

To sum up, the skull is derived (*a*) from the parachordals and the trabeculæ at the end of the notochord, (*b*) from the adjacent sense-capsules of nose and ear, (*c*) from the more

or less intimately associated mandibular and hyoid arches, (*d*) from membrane or investing bones of extrinsic origin (see the table on page 375).

The brain-box is cartilaginous in Cyclostomata and Elasmobranchs; centres of ossifications and investing bones begin with the Ganoid fishes and are numerous in Teleosteans. Above Elasmobranchs, in short, the gristly brain-box is more or less thoroughly replaced or covered by bones. In the individual development there is a parallel progress.

Theory of the Skull.

Near the beginning of this century, Oken and Goethe independently propounded what is known as the vertebral theory of the skull. They imagined that the skull was comparable to three or four vertebral bodies, and that the bones of each of the regions were comparable to the parts of a vertebra. Thus the basi-occipital, the two ex-occipitals, and the supra-occipital of the hindmost region of the skull, were held to correspond to the centrum, the neural arches, and the neural spine of a vertebral body.

But this undoubtedly suggestive theory was disproved by the subsequent discoveries of comparative anatomy and embryology. Huxley gave it a death-blow, showing that the suggested homologies were false, while Gegenbaur replaced it by what may be called the segmental theory, according to which the skull is the result of about nine primitive segments. Their number is inferred from the distribution of the cranial nerves.

Before there is any trace of skull, the head consists of nine to eleven primitive segments, like those which in the trunk give rise to myomeres, etc. But the cartilaginous skull which gradually grows is not itself segmented, still less can the primary or secondary bones of the bony skull be referred to definite segments. It is the head which is segmented, not the skull, and the segmentation of the head can be securely appreciated only from the early stages when the primitive segments are still demonstrable, though the results thus reached may be corroborated by a study of the nerves, the lateral sense-organs, the ganglia, and the arches. But the matter must still be left for a while in the hands of experts, until greater harmony of conclusion is attained.

Backbone.—The foundation of the axial skeleton is the notochord, which is formed from endoderm or hypoblast along the dorsal wall of the embryonic gut. In most Vertebrates the backbone develops as the substitute of this notochord, but not from it.

For (1) around the hypoblastic notochord there grows a mesoblastic sheath, which also extends as a membranous

Composition of the Skull.

ELEMENTS.	ORIGIN.	RESULTS.
I. Parachordals and trabeculæ, aided in some cases by the end of the notochord.	Their precise relations, *e.g.*, to the notochord, are unknown.	Occipital region, with four bones—basi-occipital, two ex-occipitals, and a supra-occipital (in part). The basi-occipital is distinct only in Reptiles, Birds, and Mammals. Sphenoidal and ethmoidal region, with basi-sphenoid and pre-sphenoid, paired alisphenoids and orbitosphenoids, the inter-orbital septum, the lateral or ecto-ethmoids, the inter-nasal septum.
II. Sense-capsules. (*a*) Nasal. (*b*) Auditory.	From cartilage surrounding the ectodermic pits which form the foundation of nose and ear.	(*a*) unite with ethmoidal region. (*b*) May give origin to five bones—pro-, sphen-, pter-, epi-, and opisth-otics, or to the single periotic of Mammals.
III. Arches. (*a*) Mandibular. (*b* Hyoid arch.	These arches, like those which follow them, are supports of the pharynx, lying between primitive or persistent gill-slits. Perhaps they may be compared to ribs.	(*a*) Upper part = palato-pterygo-quadrate cartilage of Elasmobranchs, palatine, pterygoid, and quadrate bones in the higher Vertebrates, but in Mammals the quadrate is believed by many to become the incus of the inner ear. Lower part = Meckel's cartilage—the basis of the lower jaw in all animals; the part next the quadrate becomes the articular bone, which in Mammals is believed by many to become the malleus of the inner ear. (*b*) Upper part or hyo-mandibular=the "suspensorium" cartilage of Elasmobranchs, the hyo-mandibular and symplectic of Teleosteans, the columella auris of Amphibians and Reptiles, the stapes of the Mammal's ear. Lower part=the hyoid proper cartilage or bone.
IV. Investing membrane bones. (*a*) From the roof of the skull. (*b*) On the floor of the skull, *i.e.*, from the roof of the mouth. (*c*) About the sides of the skull. (*d*) About the upper jaw. (*e*) About the lower jaw.	Originally of the nature of external bony plates, tooth structures, and the like.	(*a*) Parietals, frontals, nasals, etc. (*b*) Vomer, parasphenoid, etc. (*c*) Lachrymal, squamosal, orbitals, etc. (*d*) Premaxilla, maxilla, jugal, and quadrato-jugal (in part). (*e*) Dentary, splenial, angular, supra-angular, coronoid.

DIAGRAM XXI.

SKELETON.

Skull I. (after Wiedersheim) shows the end of the notochord (*notoch.*), the parachordals (*pa.*), the trabeculæ (*tr.*). The nasal capsule (*na.*), the position of the eye (*opt.*)., and the auditory capsule (*aud.*), are also shown.

In *Skull* II. (after Wiedersheim) the chondrocranium is developed. There is an unclosed region or fontanelle on the roof.

Below *Skull* I. is a figure marked *Ribs.* It represents (after Huxley) the skeleton in the thoracic region of a crocodile, and shows the centrum (*c.*) of a vertebra, the transverse processes (*t. p.*), the neural spine (*n. s.*), the articular processes (*z. z.*), the tubercle (*t.*) and the capitulum (*cap.*) of a rib, the upper portion of a rib (*v. r.*) bearing an uncinate process (*p. u.*), the cartilaginous (shaded) lower portion of the rib, the ventral sternum (*st.*), and the so-called sternal ribs (*st. r.*) connecting ribs and sternum.

Below this is a diagrammatic pectoral girdle, showing the relative positions of ventral coracoid (*cor.*), clavicle (*clav.*), and dorsal scapula (*scap.*).

To the right is the pelvis of a crocodile with dorsal ilium (*il.*), ventral and anterior pubis (*pub.*), ventral and posterior ischium (*isch.*).

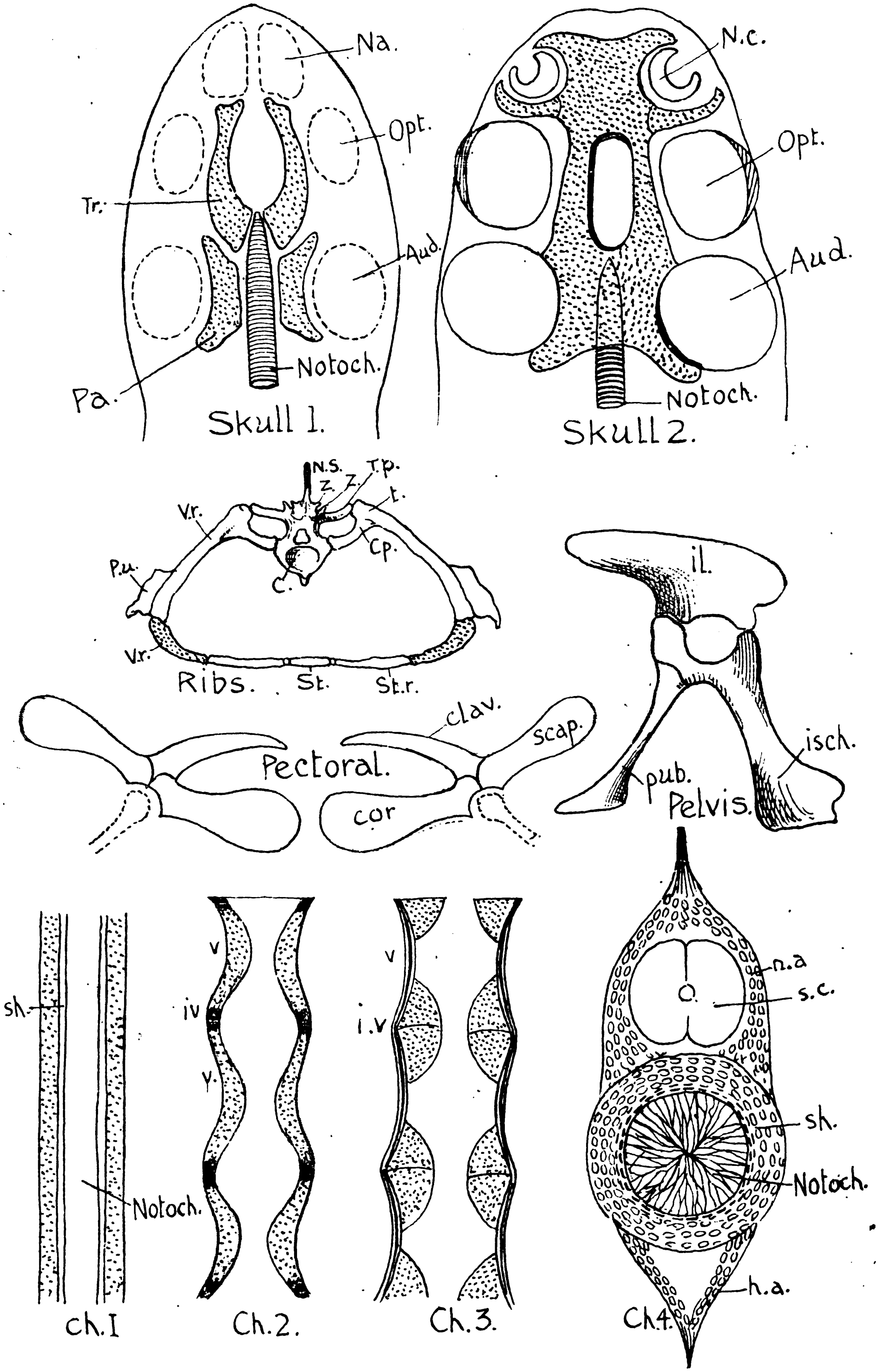
Ch. 1. represents an unconstricted notochord surrounded by its sheath (*sh.*).

Ch. 2. (after Gegenbaur) shows the vertebral constriction of the notochord by its sheath. The dark intervertebral parts (*i. v.*) indicate the limits of the resulting vertebræ.

Ch. 3. (after Gegenbaur) shows the intervertebral constriction of the notochord as it occurs in Amphibians.

Ch. 4. (after Balfour) shows a cross section of the vertebral column in a young Elasmobranch. The notochord (*notoch.*), its sheath (*sh.*), the neural arches (*n. a.*), enclosing the spinal cord (*s. c.*), and the hæmal arches (*h. a.*), are shown.

Skeleton.


Na.
Opt.
Tr.
Aud.
Notoch.
Pa.
Skull 1.
N.c.
Opt.
Aud.
Notoch.
Skull 2.
N.S.
Z.
Z.
T.p.
t.
V.r.
C.p.
C.
P.u.
V.r.
Ribs.
St.
St.r.
il.
clav.
scap.
Pectoral.
cor
isch.
pub.
Pelvis.
sh.
Notoch.
v
iv
v
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s.c.
sh.
Notoch.
h.a.
Ch.I
Ch.2.
Ch.3.
Ch.4.

tube around the spinal cord. (2) In the notochordal sheath, the formation of cartilage begins at regular intervals, corresponding to the muscle segments or myomeres, or in other words, to the primitive mesoderm segments, which used to be called proto-vertebræ. (3) Finally, ossification may occur, and a segmented backbone be established.

In *Amphioxus*, in *Myxine*, and in young lampreys (so-called *Ammocœtes*), the notochord persists, unsegmented and with a simple sheath. In the adult lamprey, there are rudimentary arches of cartilage forming a trough in which the spinal cord lies. In the cartilaginous Ganoid fishes, in the *Chimæra* type, and in the Dipnoi, arches appear both above and below, but yet there are no vertebral bodies. These begin in the Elasmobranchs, in which the notochord is constricted by its encroaching sheath. In the bony Ganoids the vertebræ are ossified, and so they are in all the higher Vertebrates. Moreover, the notochord is more and more completely obliterated as the backbone grows.

A vertebra generally consists of several more or less independent parts: the substantial centrum, the neural arches which form a tube for the spinal cord, and are crowned by a neural spine, the transverse processes which project laterally, and are, perhaps, homologous with the inferior hæmal processes in the posterior region of Fishes and some Amphibians.

The ribs which support the body-wall, and usually articulate with the transverse processes, or with the transverse processes and centra, perhaps bear the same relation to the vertebræ that the visceral arches do to the skull.

In Amphibians for the first time a breast-bone or sternum is developed. It arises from two cartilaginous rods in a tendinous region on the ventral wall of the thorax, and seems to be different from that of higher animals. For the sternum which is present in some Reptiles, and in all Birds and Mammals, arises from a cartilaginous tract uniting the ventral ends of a number of ribs.

Appendicular Skeleton.—No secure conclusion has yet been reached as to the origin of the paired limbs. According to Gegenbaur, the pectoral and pelvic girdles are homologous with branchial arches, while the primitive limbs are made up of modified fin-rays originally like those of the unpaired fins. According to Dohrn, the limbs are residues

of a longitudinal series of segmentally arranged outgrowths, perhaps comparable to the parapodia of an Annelid.

The pectoral or shoulder girdle consists of a dorsal scapular portion or shoulder-blade, a ventral coracoid portion, with the articulation for the limb between them, and of a forward growing clavicle or collar bone.

The pelvic or hip girdle consists of a dorsal iliac portion, a ventral ischiac portion, with the articulation for the limb between them, and of a pubic region possibly homologous with the clavicle.

The fore-limb—from Amphibians onwards—consists of a humerus articulating with the girdle, a lower arm composed of radius and ulna lying side by side, a wrist or carpus of several elements, a "hand" with metacarpal bones in the "palm," and with "fingers" composed of several phalanges.

The hind-limb—from Amphibians onwards—consists of a femur articulating with the girdle, a lower leg composed of a tibia and fibula lying side by side, an "ankle" region or tarsus of several elements, a foot with metatarsal bones in the "sole," and with toes composed of several phalanges.

The fin-like limbs peculiar to Fishes, are discussed along with the other characteristics of that class.

Distinct from the other bones are a few little sesamoids of occasional occurrence, *e.g.*, the knee-pan or patella. They develop in the tendons of muscles.

Nervous System.—This includes the brain, the spinal cord, and the cranial and spinal nerves. Brain and spinal cord develop from the outer layer or ectoderm of the embryo, gradually acquiring a less superficial position; from the central nervous system thus established, the nerves grow outwards to the various parts of the body.

More precisely, the central nervous system appears along the dorsal median line of the embryo, as a superficial groove of ectodermic cells. The sides of this medullary groove meet, and a medullary canal is formed. The cavity of this canal is connected posteriorly with the primitive gut of the embryo, and persists after this connection is lost as a little ciliated canal in the centre of the spinal cord, and as the internal cavity of the brain. For the brain is but an anterior expansion of the medullary canal.

The brain.—At an early stage the brain exhibits three

swellings—the three primary vesicles. Out of these *three* embryonic vesicles, the *five* regions seen in the adult brain are formed. The median vesicle corresponds to the mid-brain of the adult, while the anterior vesicle forms the first two, and the posterior vesicle the last two divisions.

The first vesicle persists in the adult in the region (2) of the optic thalami, or thalamencephalon, or tween-brain. But anteriorly from the first vesicle there arises secondarily the important region (1) of the cerebral hemispheres, or prosencephalon, or fore-brain.

The median vesicle persists in the adult in the region (3) of the optic lobes, or mesencephalon, or mid-brain.

The third vesicle persists in the adult in the region (5) of the medulla oblongata, or myelencephalon, or after-brain. But anteriorly from this third vesicle there arises the region (4) of the cerebellum, or metencephalon, or hind-brain.

Great importance must be attached to the cerebral hemispheres, prosencephalon, or fore-brain, for this region predominates more and more in the ascent of Vertebrates, and becomes more and more the home of thought. Between the longitudinal halves into which it is divided, there are several bridges or commissures. With the fore-brain olfactory lobes are also associated. The cavities of the two cerebral hemispheres are called the lateral ventricles.

With the second region—that of the optic thalami, or thalamencephalon, or tween-brain—the following important structures are associated :—(*a*) The optic outgrowths which form the optic nerves, and some of the most essential parts of the eyes; (*b*) the pineal outgrowth or epiphysis which ascends dorsally, and is interpreted with much likelihood as a rudimentary median eye; (*c*) the pituitary outgrowth or infundibulum which descends ventrally towards the mouth, and forms part of the enigmatical pituitary body or hypophysis. The cavity of the thalamencephalon is called the third ventricle.

The third region—that of the optic lobes, or mesencephalon, or mid-brain—has for its floor what are called the crura cerebri, while dorsally lie the two optic lobes, which are hollow in almost all Vertebrates. Through this mid-brain runs a canal or iter or aqueduct of Sylvius connecting the third ventricle with the fourth.

The fourth region—that of the cerebellum, or metencephalon, or hind-brain—often has lateral lobes, and usually overlaps the next region. The floor of the region of which the cerebellum forms the roof, is known as the Pons Varolii.

From the fifth region—that of the medulla oblongata or myelencephalon, or after-brain—most of the cranial nerves are given off. Its roof, partly overlapped by the cerebellum, degenerates; its cavity—called the fourth ventricle—is continuous with the canal of the spinal cord.

Summary.

First Embryonic Vesicle.	(1.) Cerebral hemispheres, prosencephalon, or fore-brain. Note commissures, olfactory lobes and nerves, and first and second ventricles.
	(2) Optic thalami, thalamencephalon, or tween-brain. Note (*a*) optic, (*b*) pineal, (*c*) pituitary outgrowths, and the third ventricle.
Median Embryonic Vesicle.	(3) Optic lobes, mesencephalon, or mid-brain. Note crura cerebri, and the aqueduct of Sylvius.
Third Embryonic Vesicle.	(4) Cerebellum, metencephalon, or hind-brain. Note Pons Varolii.
	(5) Medulla oblongata, myelencephalon, or after-brain. Note rudimentary roof, fourth ventricle, and origin of most of the cranial nerves.

The pineal upgrowth or epiphysis from the roof of the thalamencephalon is usually interpreted in one of two ways. (1) As it is associated with what seems to be an unpaired eye in the strange New Zealand reptile *Sphenodon* and in some lizards (*e.g.*, *Iguana*), it is likely that it may be in all cases a rudimentary organ associated with a lost eye. (2) But some maintain that the epiphysis is to be regarded as a remnant of the pore which remained when the folds of the medullary groove closed in anteriorly to form the brain.

The pituitary downgrowth or infundibulum from the floor

of the thalamencephalon is yet more difficult to understand. It bears at its end the pituitary body or hypophysis, part of which is derived from the brain and part from the mouth. (1) It is compared (Balfour, Julin) to the sub-neural gland of Tunicates. (2) It is hypothetically connected (Dohrn) with two abortive gill-slits. (3) It is hypothetically interpreted (Beard) as a residuum of the original mouth which Vertebrates are supposed to have possessed before the persistent one with which we are familiar was evolved, and of the innervation of that hypothetical structure.

Cranial Nerves.—The origin and distribution of the cranial nerves may be summarised as follows:—

NAME.	ORIGIN.	DISTRIBUTION.	NOTES.
1. Olfactory. *s.**	Upper part of fore-brain.	Nostrils.	
2. Optic. *s.*	Optic thalami.	Eye.	Rather parts of the brain than nerves. They cross before they enter the brain, and generally unite at their intersection.
3. Oculo-motor or ciliary. *m.**	Crura cerebri.	All the muscles of the eye but two.	A ciliary ganglion at roots.
4. Pathetic or trochlear. *m.*	Beneath the front of cerebellum.	Superior oblique muscles of the eye.	Perhaps belongs to 5.
5. Trigeminal. *s.* and *m.*	Medulla oblongata.	(1) Orbito-nasal or superficial ophthalmic to snout. (2) Maxillary to the upper jaw, etc. (3) Mandibular to lower jaw, lips, etc.	Gasserian ganglion at roots. The nature of the ophthalmicus profundus, often included with 5, sometimes with 3, is doubtful.
6. Abducens. *m.*	,,	External rectus of eye.	Perhaps belongs to 7.
7 Facial, chiefly *m.* partly *s.*	,,	(1) Hyoidean. (2) Palatine. (3) Buccal.	
8. Auditory. *s.*	,,	Ear.	Ganglion at the roots of 7 and 8.
9. Glossopharyngeal. *s.* and *m.*	,,	First gill-cleft region, pharynx, etc.	
10. Vagus or Pneumogastric. *s.* and *m.*	,,	Gills, heart, gut and body generally.	Apparently a complex, including the elements of four or five nerves.

* The letter *s.* is a contraction for sensory or afferent, *i.e.*, transmitting impulses from a sensitive area to the centre; and *m.* is a contraction for motor or efferent, *i.e.*, transmitting impulses from the centre to the body.

There is much uncertainty in regard to the morphological value of the various cranial nerves, but the following conclusions are important:—

(1) The nerves arise as outgrowths of the central system. Each spinal nerve has two roots—a dorsal and a ventral, but in most cases at least a cranial nerve has primitively a single dorsal root arising from a neural ridge of the dorsal surface of the brain. In many cases this root divides into "dorsal," "ventral," etc., branches. As these typically innervate a gill-slit, as may be well studied in 9, the branches may be called (as Beard proposes) supra-branchial (dorsal), post-branchial, præ-branchial, etc. In the course of growth the nerve often shifts from the position whence its root originated.

(2) Some of them mark distinct segments of the head, while others are secondary derivatives. It is likely that 1, 3, 5, 7, 8, 9, and several parts of 10 mark segments. It is possible that the oculo-motor is a ventral root associated with the third or ciliary nerve, that the trochlear is a ventral root of the trigeminal, that the abducens is a ventral root of the facial.

(3) It is possible that each truly segmental nerve supplied a primitive gill-slit, as 7 supplies the spiracle, 9 the first branchial, 10 the second, third, fourth, and fifth branchials.

(4) It is likely that each segmental nerve was associated with a branchial sense-organ (Beard and Froriep). These organs occur about the gills, and are continued in the lateral line of the trunk. It is likely that a branchial sense-organ lay over each primitive gill-cleft, and had an associated ganglion. The ganglia known as ciliary, gasserian, etc., may be the ganglia of branchial sense-organs. It may be that nose and ear were originally branchial sense-organs.

The Spinal Cord.—The spinal cord arises like the brain from the medullary groove, whose sides fold over and form a medullary canal.

This canal is for a time continuous posteriorly with the food-canal beneath, so that a ⊃-shaped tube results. The connection between them is called the neurenteric canal, and though it is only temporary its constant occurrence is of much interest.

As the medullary canal sinks in and becomes differentiated into the spinal cord, its cavity becomes a relatively minute ciliated canal, while the walls become very thick.

In some cases at least the spinal cord has from the first a distinct bilateral symmetry; and this is always emphasised by longitudinal fissures, which run along it dorsally and ventrally.

Each spinal nerve has two roots—a dorsal, posterior, or sensory, and a ventral, anterior, or motor. These arise separately and independently, but combine in the vicinity of the cord to form a single nerve. The posterior root exhibits at an early period a large ganglionic swelling—the spinal ganglion; the anterior root is apparently non-ganglionated, but some modification of this statement will be found below. Moreover, the posterior or dorsal root has always a single origin (as in the cranial nerves), while that of the anterior or ventral root is often multiple.

But consider the origin of the spinal nerves more precisely. The posterior roots are outgrowths of a continuous ridge or crest along the median dorsal line of the cord. As the cord grows the nerve-roots of each side become separated. They shift sidewards and downwards, and acquire a secondary attachment to the side of the cord, while the primary attachment disappears. The anterior roots are later in arising; they spring from the latero-ventral angle of the cord; they retain their original attachment.

Beard has shown in several cases that the spinal ganglia have an independent epiblastic origin by the sides of the medullary canal.

According to some authorities, the sympathetic ganglia are off-shoots from the same rudiment as that from which the posterior or dorsal ganglia arise, and it is possible that they are the more or less vagrant ganglia of the anterior or ventral roots, with which they are connected by small fibres. On this view (Gaskell's) both roots may be said to be ganglionated. But the ganglion of the dorsal or posterior root is stationary in position, and the nerve fibres which pass through it come both from the visceral (splanchnic) and from the peripheral parts (somatic), separating from one another within the cord. On the other hand, the supposed ganglion (sympathetic) of the ventral or anterior root is more or less vagrant, and off the main line of the root, from which it receives small fibres passing to splanchnic or visceral structures.

In the spinal cord it is usually easy to distinguish an external region of white matter or medullated nerve-fibres from an internal region of gray matter or ganglionic cells. The minute central canal is lined by ciliated epithelium.

The central canal is continuous with the cavity of the brain, and is a remnant of the original medullary canal. It can hardly be said to have any function; it may be simply the result of a developmental necessity. But Sutton and Gaskell have independently suggested that the central canal of the nervous system represents a disused

DIAGRAM XXII.

Nervous System.

The longitudinal section of the brain, *Sect. Brain* (after Wiedersheim and Huxley), shows 1. the fore-brain, with olfactory outgrowths (*olf.*), and ganglionic corpus striatum (*c. s.*) on its floor; 2. the tween-brain, with pineal outgrowth (*p.*) above, infundibulum (*i.*) bearing the hypophysis (*h.*) beneath, and optic nerves (*opt.*) running forward; 3. the optic lobes; 4. the cerebellum; 5. the medulla oblongata, with its thin roof; the spinal cord (*s. c.*). Beneath lies the notochord (*N. ch.*).

The figure named *Sp. canal* shows (after Sutton) the three primary vesicles (*a. b. c.*) of the brain, the pineal upgrowth (*p.*), the hypophysis (*H.*), the notochord (*N. ch.*), the gut (*G.*), the neurenteric canal (*N.*), the yolk-sac (*Y.*).

Beneath is a diagrammatic section of the spinal cord, showing the dorsal furrow (*d. f.*), the ventral furrow (*v. f.*), the minute canal in the centre, the external white matter (*w. m.*), the internal grey matter (*g. m.*), the dorsal, anterior, or sensory roots (*d. a. s.*) with a ganglion, the ventral, posterior, or motor roots (*v. p. m.*), their union in a nerve, the sympathetic ganglia (*s. g.*) connected to the ventral roots.

The figure *Ear* (after Balfour) shows the primitive auditory vesicles or insinkings (*au. v.*), the brain (*br.*), the notochord (*N. ch.*).

The figure *Nose* (after Balfour) shows the primitive nasal pits (*olf.*), the adjacent olfactory lobes (*olf. v.*) of the cerebral hemispheres (*c. h.*).

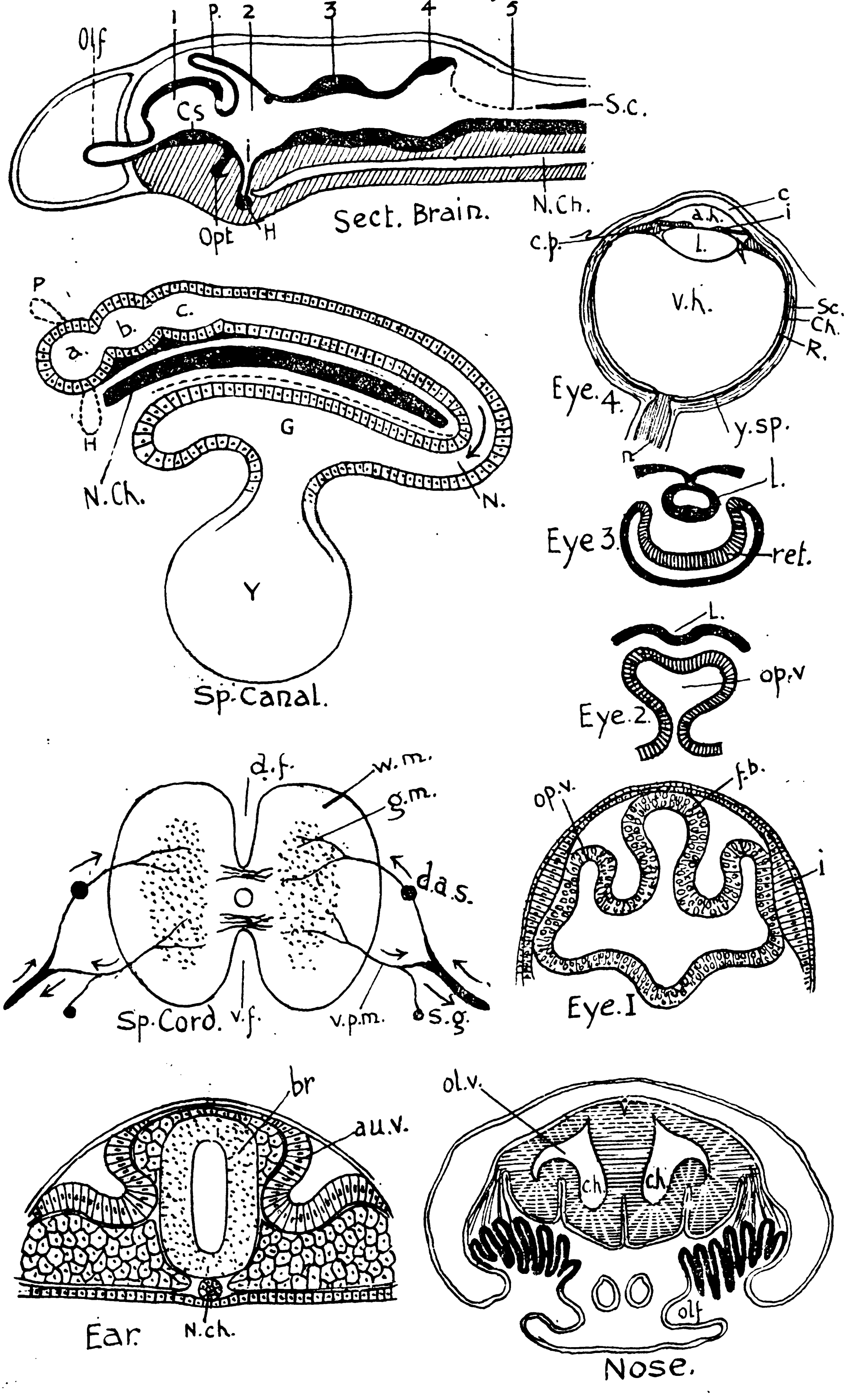
Eye I. (after Balfour) shows the origin of optic vesicles (*op. v.*) from the fore-brain (*f. b.*), and the pad of skin (*l.*) which will form the lens.

Eye II. (after Balfour) shows the relation of the lens (*l.*) to the in-dimpling optic vesicle (*op. v.*).

Eye III. (after Balfour) shows how the lens (*l.*) and the retina (*ret.*) are formed.

Eye IV. (from Hatschek, after Arlt) shows a horizontal section of the human eye. The cornea (*c.*), aqueous humour (*a. h.*), iris (*i.*), lens (*l.*), ciliary process (*c. p.*), vitreous humour (*v. h.*), retina (*r.*), choroid (*ch.*), sclerotic (*sc.*), yellow spot (*y. sp.*), optic nerve (*n.*), and its sheath are indicated.

Nervous System.



alimentary passage, which has been replaced by surrounding nervous material, and which ceased to be functional when the permanent gut became a tube open at each end.

In the brain the grey matter forms the ganglionic masses of the optic thalami, the optic lobes, and the medulla oblongata, and is covered by a layer of white matter. In the cerebellum, and in the cerebral hemispheres, the superficial layer of white matter is very thin; in both the grey matter forms a cortex beneath the superficial white layer, in the cerebral hemispheres internal ganglionic masses as well; in both, moreover, white matter occurs again within the grey.

In Cyclostomata, Ganoids, and Teleosteans, the fore-brain has no nervous roof, but is covered by an epithelial pallium homologous with what is called the choroid plexus of the third ventricle in higher Vertebrates. This choroid plexus is a thin epithelium, with blood-vessels in it. But in Elasmobranchs, Dipnoi, and Amphibians the basal parts of the fore-brain have grown upwards to form a nervous roof, and this persists in higher Vertebrates. The roof of the fourth ventricle is always thin and epithelial in adults.

Enswathing the brain and following its irregularities is a delicate membrane—the pia mater—rich in blood-vessels which supply the nervous system. Outside this in higher Vertebrates there is another membrane—the arachnoid—which does not follow the minor irregularities of the brain so carefully as does the pia mater. Thirdly, a firm membrane—the dura mater—lines the brain-case, and is continued down the spinal canal. In lower Vertebrates the dura mater is double, in higher Vertebrates it is so in the region of the spinal cord, where the outer part lines the bony tunnel, while the inner ensheathes the cord itself. In Fishes the brain-case is much larger than the brain, and a large lymph space lies between the dura and the pia mater.

Sense-Organs.—The central nervous system has doubtless arisen in the course of history from the insinking of external nerve-cells; it does arise in development as an involution of ectoderm or epiblast. The same layer gives origin to the sense-organs, the nose, the ear, and the sensory structures of the skin. The Vertebrate eye is somewhat divergent, for it is formed in great part as an outgrowth from the brain, but

as the brain is itself an involution of epiblast, the eye may be also referred to external nerve-cells.

(*a*) Branchial Sense-Organs.—In many Fishes and Amphibians there are lateral sense-organs which form the "lateral lines," while the more anterior and more primitive are connected with gill-clefts, or in all likelihood were connected with gill-clefts which have disappeared. In Sauropsida and Mammals these branchial sense-organs are no longer distinct as such.

(*b*) The Nose.—It is possible that the sensory pits of skin which form the nasal sacs are two branchial sense-organs. They are lined by epithelium in great part sensory, and are connected posteriorly with the olfactory nerves. In all Fishes, except Dipnoi, the nasal sacs remain blind; in Amphibians, and in all the higher Vertebrates, they open posteriorly into the cavity of the mouth, and serve for the entrance of air. The peculiar nostril of hagfish and lamprey is referred to in the chapter on Cyclostomata, pp. 404, 406.

(*c*) The Ear.—From an involution of epiblast the ear also develops, and perhaps it also is a branchial sense-organ. The narrowed neck of the involution, originally opening externally, persists in this primitive state in some Elasmobranchs, but usually ends in the dura mater of the skull. It is called the aqueductus vestibuli, or the ductus endolymphaticus.

The cavity or vestibule of the ear is divided into a larger utriculus, and a smaller sacculus. Round the utriculus three semi-circular canals are formed, except in the lamprey which has only two, and in the hagfish which has only one. From the sacculus an outgrowth called the cochlea or lagena originates; it is little more than a small hollow knob in Fishes and Amphibians, but becomes large in Sauropsida and Mammals.

The whole cavity of the ear is called the membranous labyrinth, and contains a fluid called endolymph, but it becomes ensheathed in mesoblast, which forms a cartilaginous or bony labyrinth. Between the membranous labyrinth and its external sheath there is a fluid called perilymph.

Within the ear are various patches of sensory epithelium with branches of the auditory nerve. There are calcareous concretions (otoliths) near the sensory patches, except in the cochlea of Mammals.

In Fishes there is rarely any special path by which impressions of sound travel from the outer world to the ear. In frogs and higher Vertebrates, however, the ear has sunk further into the recesses of the skull, and a special path for the sound is necessary. The hyo-mandibular or spiracular gill-cleft, near which the ear originally lies, is replaced by an outgrowth from the pharynx called the Eustachian tube. The outer part of this outgrowth expands into a tympanic cavity, across which there stretches a drum or tympanum. In the frog this tympanum lies on the surface of the head, and is connected with the capsule of the ear by a rod known as the columella. The inner end of this closes a small aperture—the fenestra ovalis—in the wall of the ear-capsule. In higher Vertebrates there is an external chamber or meatus outside the tympanum, and the columella—which persists in Sauropsida—is replaced in Mammals by three ossicles, an outermost malleus, a median incus, an internal stapes. It is only in Mammals, and not in all of them, that we find a pinna or external projection around the opening of the external chamber of the ear. From the tympanic cavity, the Eustachian tube is continued down to the back of the mouth.

The homologies of the little ossicles which connect the drum with the ear-capsule are not quite certain. I adhere in the meantime to the following interpretation :—

Columella of Birds, Reptiles, and Amphibians = Stapes of Mammals = Hyomandibular or upper part of the hyoid arch.

Incus of Mammals = Quadrate of Sauropsida.

Malleus of Mammals = Articular element of Meckel's cartilage.

(*d*) The Eye.—There is no eye in *Amphioxus*, it is rarely more than larval in Tunicates, it is degenerate in *Myxine*, and in the young lamprey. In higher forms the eye is always present, though occasionally degenerate, *e.g.*, in fishes from caves or from the deep-sea. It is hidden under the skin in *Proteus*, an amphibian cave-dweller, and in the subterranean amphibians like *Cæcilia*, very small in a few snakes and lizards, and abortive as to its nerves in the mole.

The adult eye is more or less globular, and its walls consist of several distinct layers. The innermost layer bounding

the posterior part of the globe is the sensitive retina, innervated by fine branches from the optic nerve. It may be compared to the nervous matter of the brain, from which, indeed, it arises. Outside of the retina is a pigmented epithelium, and outside of this a vascular membrane; together these are often called the choroid. The vascular part may be compared to the pia mater of the brain, and like it is derived from mesoblast. Outside of the choroid is a protective layer or sclerotic, comparable to, and continuous with, the dura mater of the brain, and also mesoblastic in origin. Occupying the front of the globe is the crystalline lens, a clear ball derived directly from the skin. It is fringed in front by a pigmented and muscular ring—the iris, which is for the most part a continuation of the choroid. The space enclosed by the iris in front of the lens is called the pupil. Protecting and closing the front of the eye is the firm cornea continuous with the sclerotic, and covered externally by the conjunctiva—a delicate epithelium continuous with the epidermis. Between the cornea and the iris is a lymph space containing aqueous humour, while the inner chamber behind the lens contains a clear jelly—the vitreous humour. The lens is moored by "ciliary processes" of the choroïd, and its shape is alterable by the action of accommodating muscles arranged in a circle at the junction of iris and sclerotic. In many Fishes and Reptiles, and in Birds, a vascular fold called the pecten projects from the back of the eye into the vitreous humour. The retina is a very complex structure with several layers of cells, partly supporting and partly nervous, but suffice it to say that the layer next the vitreous humour consists of nerve-fibres, while that furthest from the rays of light and next the pigment-epithelium consists of sensitive rods and cones. The region where the optic nerve enters, and whence the fibres spread, is called the blind spot, while near this there lies the most sensitive region—the yellow spot, with its fovea centralis, where all the layers of the retina have thinned off except the cones.

Among the extrinsic structures, must be noted the six muscles which move the eye-ball, the upper and lower eyelids which are often very slightly developed, the third eyelid or nictitating membrane. Above Fishes there is a lachrymal gland associated with the upper lid, and a Harderian gland

associated with the nictitating membrane. In Mammals there are also Meibomian glands. The secretions of all these glands keep the surface of the eye moist.

While the medullary groove is still open, the eyes arise from the first vesicle of the brain as hollow outgrowths or primary optic vesicles. Each grows till it reaches the skin, which forms a thickened involution in front of it. This afterwards becomes the compact lens. Meantime it sinks inwards, and the optic vesicle becomes invaginated into a double-walled optic cup. The two walls fuse, and the one next the cavity of the cup becomes the retina, while the outer forms the pigmented epithelium. Meanwhile surrounding mesoblast has insinuated itself past the lens into the cavity of the optic cup, there forming the vitreous humour, while externally the mesoblast also forms the vascular choroid, the firm often cartilaginous sclerotic, the inner layer of the cornea, etc. The thinned stalk of the optic cup persists as the optic nerve, whose protective sheath is continuous with the sclerotic of the eye and the dura mater of the brain. As the nerves enter the optic thalami, they always cross one another in a chiasma, and their fibres usually interlace as they cross.

The Alimentary System and Associated Structures.—The alimentary tract exhibits much division of labour, for not only are there parts suited for the passage, digestion, and absorption of the food, but there are numerous outgrowths, *e.g.*, lungs and allantois, which have nothing to do with the main function of the food-canal.

By far the greater part of the food-canal is lined by endoderm or hypoblast, and is derived from the original cavity of the gastrula—the primitive gut or archenteron. This we shall call the mid-gut, using occasionally the more technical name mesenteron. But the mouth cavity is lined by ectoderm, invaginated from in front to meet the mesenteron. This region we shall call fore-gut, using occasionally the technical term stomatodæum. Finally, there is usually a slight posterior invagination of ectoderm, forming the anus. This we shall call the hind-gut, occasionally using the technical term proctodæum. It should be noted, that many anatomists use the terms fore-gut, mid-gut, hind-gut, for divisions of the mesenteron, but this contradicts a usage

which is convenient, especially in regard to Invertebrates, where the fore-gut or stomatodæum and the hind-gut or proctodæum are often large.

Associated with the mouth-cavity or stomatodæum are (*a*) teeth (ectodermic rudiments of enamel combined with a mesodermic papilla which forms dentine or ivory); (*b*) from Amphibians onwards special salivary glands; (*c*) a tongue or muscular and sensitive outgrowth from the floor. In Dipnoi and higher animals, the nasal sac opens posteriorly into the mouth; in some Reptiles and Birds, and in all Mammals, the cavity of the mouth is divided by a palate into an upper nasal and lower buccal portion.

The origin of the oral aperture is not quite certain. In Tunicates it is formed by an ectodermic insinking which meets the archenteron; in *Amphioxus* it seems to be formed as a pore in an ectodermic disc; in other cases it is either a simple ectodermic invagination or stomatodæum, or it may have resulted from the coalescence of an anterior pair of gill-clefts innervated by the fifth nerve. If so, its origin well illustrates that change of function which seems to have been a frequent occurrence in evolution. But if the mouth arose from a pair of gill-clefts, and in some cases it actually has a paired origin, then there must have been an older mouth to start with. Thus Beard in his brilliant morphological studies, distingüishes between "the old mouth and the new." The new mouth is supposed to have resulted, as Dohrn suggested, from a pair of gill-clefts; the old mouth was an antecedent stomatodæum, of which the so-called nose of *Myxine* and the oral hypophysis of higher forms are vestiges. This theory harmonises with the observations of Kleinenberg, on the development of the mouth in some Annelids (*Lopadorhynchus*), in which the larval stomatodæum is replaced by a paired ectodermic invagination.

The mouth-cavity leads into the pharynx, on whose walls are the persistent gill-clefts. Of these the maximum number is eight, for the hundred slits in *Amphioxus* cannot be directly compared with the ordinary clefts. If we exclude the hypothetical clefts, such as those which are possibly represented in the mouth, the first pair form the spiracles—well seen in skates. In the position of the spiracles the Eustachian tubes of higher Vertebrates develop. In front of the spiracle there is sometimes a spiracular cartilage, which we did not mention in discussing the skull. This Dohrn dignifies as a distinct arch. The other gill-clefts are associated with gills in Fishes and Amphibians, while in Sauropsida and Mammals, in which there are no gills, four "visceral" clefts

persist as practically functionless residual structures. In some cases they do not even open. The clefts are supported by the branchial arches described in connection with the skull, and are supplied by blood-vessels.

With the most anterior part of the alimentary canal, two strange structures are associated—(*a*) the thyroid arising as a ventral constriction, perhaps comparable to the endostyle of Tunicates, perhaps substituted for a pair of gill-clefts; (*b*) the thymus arising in connection with the posterior gill- or visceral-clefts. Very little is known in regard to the function of these bodies, but the thyroid is connected with the blood supply to the head, while the thymus usually atrophies in the adolescence of higher Vertebrates.

The pharynx leads into the gullet or œsophagus, which is a conducting tube, and this into the digestive stomach, which is followed by the digestive and absorptive and conducting intestine, ending in the rectum and anus.

From the œsophagus, the air- or swim-bladder of most Fishes, and the lungs of higher Vertebrates, grow out. The air-bladder lies dorsally and is almost always single; the lungs lie ventrally and are double, though connected with the gullet by a single tube. It is not certain that these outgrowths are homologous, though the air-bladder of Dipnoi acquires the functions of a lung.

The beginning of the intestine gives origin to the liver which regulates the composition of the blood and secretes bile, and to the pancreas which secretes digestive juice.

From the hindmost region of the gut, the allantois grows out in all animals from Amphibians onwards. In Amphibians this is simply a bladder; in the higher Vertebrates it is a birthrobe, respiratory or nutritive, or both.

In a few cases, the end of the alimentary canal is simply the opening or blastopore of the original gastrula cavity or archenteron. This is true in the lamprey, and in at least several Amphibians such as frog and newt. In other cases, an ectodermic invagination or proctodæum meets the closed archenteron.

Behind the anus, there is in some embryos what has been called the "post-anal gut." It seems very likely that this is connected with the neurenteric canal, which unites the dorsal nervous tube with the ventral alimentary tube.

ALIMENTARY SYSTEM.—SUMMARY.

REGION OF THE GUT.	OUTGROWTHS.	ASSOCIATED STRUCTURES.
Mouth-cavity, or Stomatodæum, or Fore-gut, originating as an epiblastic or ectodermic invagination, or from two gill-clefts.		Teeth. Salivary glands. Tongue. (Note relation between the mouth and the oral part of the hypophysis.)
Pharynx, gullet or œsophagus, stomach, small intestine, large intestine, and rectum; = the mesenteron or mid-gut, originating from the cavity of the gastrula, the archenteron or primitive gut; lined by endoderm or hypoblast.	Thyroid, Thymus, and the gill- or visceral-clefts. Air-bladder; lungs. Liver. Pancreas. Allantois.	With the several outgrowths the surrounding mesoderm or mesoblast becomes associated often to a great extent. (Note also the origin of the notochord as an axial differentiation of cells along the mid-dorsal line of the embryonic gut.)
Anal Region, or Proctodæum, or Hind-gut. Where the mouth of the gastrula persists, it forms the terminal aperture of the gut, and then there is no ectodermic invagination or proctodæum.		In some Fishes, all Amphibians, all Sauropsida, and the Prototherian Mammals, the terminal part of the gut is a cloaca or common chamber into which the rectum, the urinary and the genital ducts open.

Body-Cavity.—In *Amphioxus* the body-cavity or cœlome arises as a paired pouch (enterocœle) from the archenteron. It afterwards becomes divided from before backwards into compartments. In other cases, the body-cavity seems to appear as a cleft (schizocœle) in the mesoderm, or it may be formed by some reduced and disguised form of pouching.

Vascular System.—From Cyclostomata onwards the blood fluid contains red corpuscles, *i.e.*, cells coloured with hæmoglobin — a pigment which readily forms a loose union with oxygen, and bears this from the exterior (gills or lungs) to the tissues. These pigmented cells are usually oval and nucleated. In all Mammals except Camelidæ they are circular. Moreover, the full-grown red corpuscles of Mammals have no visible nuclei. The blood fluid also contains nucleated uncoloured amœboid cells, the white corpuscles

or leucocytes, of much physiological importance, *e.g.*, as bearers of food-particles from one part of the body to another.

The heart or central organ of the circulation receives blood from veins, and drives it forth through arteries. Its activity is the chief cause of the inequality of pressure which makes the blood flow. It lies in a special part of the body-cavity known as the pericardium, and develops from a single blood vessel in Cyclostomata, Fishes, and Amphibians, from a pair in Reptiles, Birds, and Mammals.

The receiving region of the heart is formed by an auricle or by two auricles, thence the blood passes into the muscular ventricle or ventricles, and is driven outwards. Except in adult Birds and Mammals the veins from the body enter the auricle (or the right auricle if there are two) by a porch known as the sinus venosus. In all Fishes except Teleosteans and in Amphibians, the blood passes from the ventricle into a valved conus arteriosus which seems to be a continuation of the ventricle In Teleosteans there is a superficially similar structure, but without valves and non-contractile, and apparently developed from the aorta not from the ventricle; it is called the bulbus arteriosus, and may occur along with the conus arteriosus in other Fishes. In Vertebrates higher than Amphibians these parts have virtually disappeared.

In Cyclostomata, and in all Fishes except Dipnoi, the heart has one auricle and one ventricle. In these animals the heart contains only impure blood, which it receives from the body and drives to the gills, whence purified it flows to the body.

In Dipnoi, the heart has two auricles, and there is a slight partition in the ventricle.

In Amphibians, the heart has two auricles and a ventricle. The right auricle always receives venous or impure blood from the body, the left always receives arterial or pure blood from the lungs. The single ventricle of the Amphibian heart drives the blood to the body and to the lungs.

In all Reptiles, except Crocodilia, the heart has two auricles and an incompletely divided ventricle. By means of the partition in the ventricle much of the venous blood is sent to the lungs; indeed the heart, though possessing only three chambers, works almost as if it had four.

DIAGRAM XXIII.

Circulatory System.

Fig. 1 is a diagrammatic representation of the chambers of, or connected with the heart : *S. v.* the sinus venosus, *A.* the auricle, *V.* the ventricle, *C. a.* the conus arteriosus, *B. a.* the bulbus arteriosus. (After Wiedersheim.)

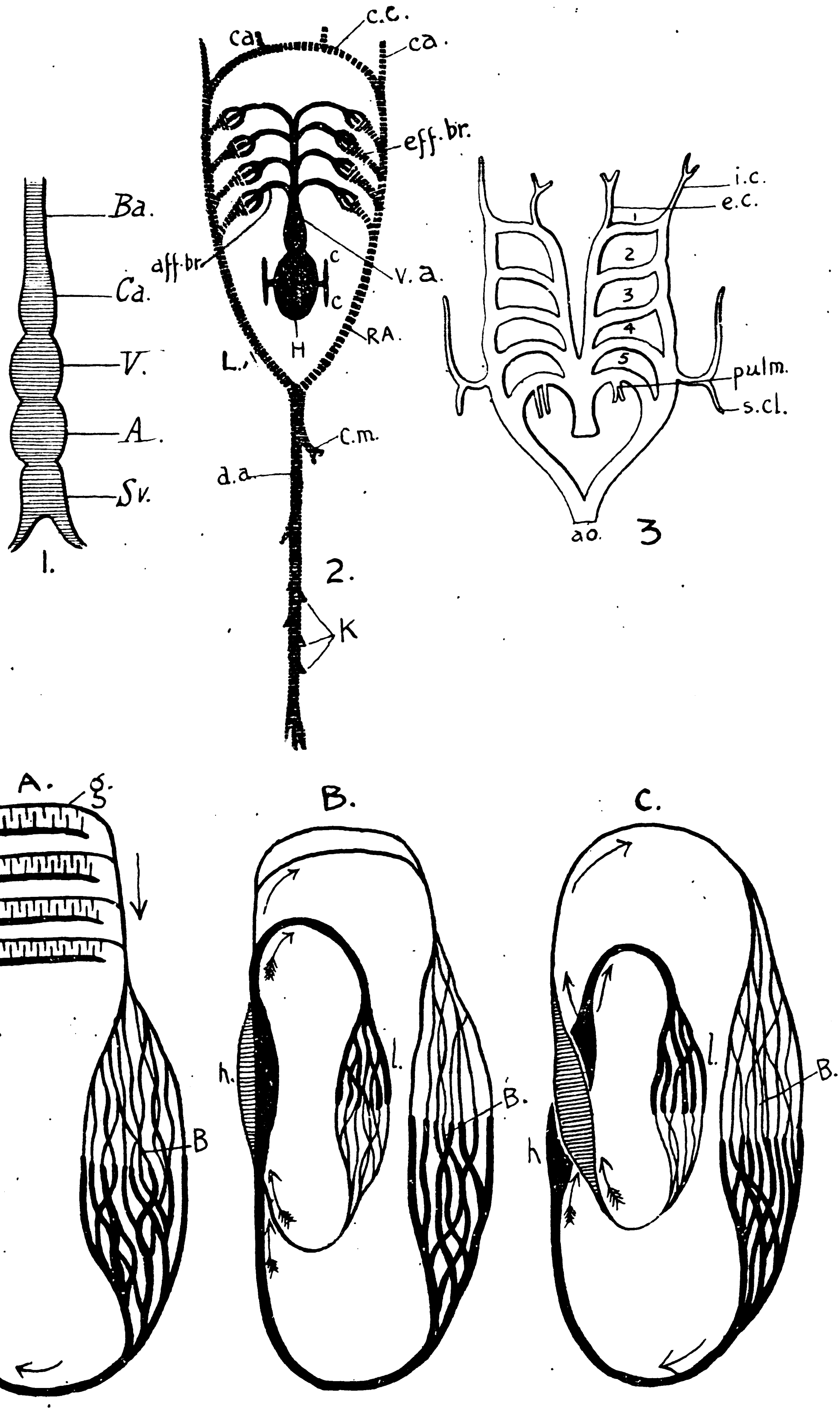
Fig. 2 represents the typical vascular system of a fish :—*H.* the heart, *c.* the cardinal veins entering it, *v.a.* the ventral aorta, giving off afferent branchial vessels (*aff. br.*) to the gills, whence efferent branchial vessels (*eff. br.*), unite on each side as right and left aortic trunks (*R. A.*, *L. A.*). These may unite in front in a cephalic circle (*c. c.*), they give off anteriorly the carotids (*ca.*). Posteriorly the arterial trunks unite to form the dorsal aorta (*d. a.*), from which arteries, *e.g.*, the cœliaco-mesenteric (*c. m.*), and the renals (*k.*), &c., are given off. (After Wiedersheim.)

Fig. 3 represents the five embryonic vascular arches in a Reptile :—*ao.* the dorsal aorta, *pulm.* the pulmonary artery, *s. cl.* subclavian, *i.e.*, and *e. c.* internal and external carotids. (After Hertwig.)

A. B. and C. (after Hatschek) are diagrams of the circulation in Fish (A.), Amphibian (B.), and Bird or Mammal (C.).

H. the heart, *g.* the gills, *L.* the lungs, *B.* the body. The venous channels are dark, the arterial lighter. The arrows indicate the direction of the flow.

Circulatory System.



In Crocodilia, there are two auricles and two ventricles. But the dorsal aorta, which supplies most of the body, is formed from the union of two aortic arches, one from each ventricle. Therefore it contains mixed blood.

In Birds and Mammals, the heart has two auricles and two ventricles, and one aortic arch supplying the body with wholly pure blood. Impure blood from the body enters the right auricle, passes into the right ventricle, is driven to the lungs, returns purified to the left auricle, enters the left ventricle, and is driven to the body.

The arterial system of a fish consists of a ventral aorta continued forwards from the heart, of a number of arching vessels diffusing the impure blood on the gills, of efferent vessels collecting the purified blood into a dorsal aorta which runs along under the backbone and supplies the body.

So in the embryo of higher Vertebrates the same arrangement persists, though there are no gills beyond Amphibians. From a ventral arterial stem arches arise, which are connected so as to form the roots of the dorsal aorta. This aorta gives off vessels to the body, while in embryonic life it sends important vitelline arteries to the yolk, and (in Reptiles, Birds, and Mammals) equally important allantoic arteries to the allantois.

Returning to the arterial system of a fish, we must consider the arches more carefully, and compare them with those of Sauropsida and Mammals, where they are no longer connected with functional gill-clefts, and also with those of Amphibians, where the complications due to lungs, etc., begin.

FISHES.	AMPHIBIANS.	SAUROPSIDA AND MAMMALS.
(*a*) Mandibular aortic arch usually aborts; has a persistent trace in Elasmobranchs (spiracular artery).	Aborts, or is not developed.	At most merely embryonic.
(*b*) Hyoid aortic arch aborts, or is rudimentary, persists in Elasmobranchs and some Ganoids.	Aborts.	At most merely embryonic.
(*c*) 1st branchial.	Carotid.	Carotid.
(*d*) 2nd branchial	Systemic arches, unite to form dorsal aorta.	Systemic. Only the right persists in Birds; only the left in Mammals.
(*e*) 3rd branchial.	Rudimentary or disappears.	Pulmonary (perhaps this is the 6th).
(*f*) 4th branchial (gives off artery to "lung" of Dipnoi).	Pulmonary.	(Perhaps it is the 5th which disappears.)

The important elements of the venous system are as follows :—

(*a*) A sub-intestinal vein leading into the heart forms posteriorly the caudal vein, and anteriorly the vitelline veins. The latter are at first connected with the yolk, but persist in the hepatic-portal system, in which veins from the intestine pass into the liver.

(*b*) Returning to the heart from the head region are two anterior cardinals, returning from behind are two posterior cardinals. These are really the forward and backward continuations of the duct of Cuvier,—a short cross vein on each side by which the united cardinals enter the heart or sinus venosus. In Fishes the anterior cardinals persist, and the posterior cardinals unite with the above-mentioned caudal vein, and also form in part the renal-portal system, in which venous blood from the posterior parts passes through the kidneys on its way to the heart. In other Vertebrates, the cardinals are for the most part replaced by superior venæ cavæ (into which the anterior cardinals open as external jugulars), and by an inferior vena cava, which receives at least the efferent veins from the kidneys and the hepatic veins from the liver.

(*c*) In Amphibia and Reptiles some of the blood from the hind limbs and from the allantoic outgrowth passes into the hepatic-portal system *via* the epigastric vein or veins. In Birds and Mammals this arrangement is found only in the embryos.

The vascular system is developed in the mesoblast from the hollowing out of strands of cells, the outer cells forming the walls of the vessels, the inner cells forming blood-corpuscles. But it may be that some elements of the blood are endodermic.

Associated with the vascular system is the spleen, which in at least some Vertebrates is a blood-making organ. It always lies in the mesentery near the stomach.

Developed in mesoblastic spaces, and continuous with the body-cavity on the one hand and the blood-vessels on the other, is the system of lymphatic spaces and vessels. The lymph fluid therein contained is derived from the capillaries by exudation or filtration. Specially important is the chyle-absorbing lacteal part of the lymphatic system by which food passes from the intestine into the blood. (See Chapter I. pp. 17, 18.) The force which propels the lymph is the same as that which drives the blood.

Respiratory System.—In *Balanoglossus*, Tunicates, and *Amphioxus*, the walls of the pharynx bear slits, between which the blood is exposed in superficial blood-vessels to the purifying and oxygenating influence of the water.

In Cyclostomata, Fishes, all young and some adult Amphibians, there are not only clefts on the walls of the pharynx, but gills associated with these. On the large surface of the feathery or plaited outgrowths, the blood is exposed and purified.

In Reptiles, Birds, and Mammals, traces of gill-clefts persist in the embryos; but they do not serve any respiratory

purpose. In the embryo the blood is kept normal, as will be explained afterwards, by aid of the birthrobe known as the allantois; and after birth the animals breathe by lungs. All adult Amphibians also have lungs, to which the air-bladder of Dipnoi is physiologically equivalent.

The gill-clefts arise as outgrowths of the endodermic gut which meet the ectoderm and open. The ventral paired lungs arise from an outgrowth of the gut, and such also is the air-bladder of most Fishes, though that usually lies on the dorsal surface, has rarely more than a hydrostatic function, and has a blood-supply different from that of the lungs. That lung and air-bladder are homologous is by no means certain, but the comparison is plausible.

Excretory System.—From Cyclostomata onwards there is a paired kidney. In the embryo this consists of a number of segmentally arranged tubules or nephridia, and these are connected on each side by a longitudinal segmental duct, which seems to have an epiblastic origin, and extends from the front of the body-cavity to the cloaca. The primitive tubules are comparable to, and perhaps homologous with, the nephridia of Annelids. According to their position they are distinguished as forming head-, mid-, and hind-kidney, or pro-, meso-, meta-nephros; but these three regions are never developed in one organism; and some of the original tubules usually lose their excretory function or atrophy. In its typical form, each nephridium consists (*a*) of an internal ciliated funnel (nephrostoma) opening into the body-cavity, but rarely persistent; (*b*) of a dilatation (Malpighian body) into which blood-vessels project; and (*c*) of a coiled tube in part excretory, in part a conducting canal for the waste filtered from the blood. The segmental or archinephric duct on each side is usually divided into, or it may be replaced by two ducts, the Müllerian duct and the mesonephric or Wolffian duct. The Müllerian duct becomes the genital duct or oviduct of the female, while in the male the Wolffian duct becomes the genital duct or vas deferens. The ureters or ducts from the persistent functional kidneys, are either the archinephric ducts (*e.g.*, in Cyclostomata), or the Wolffian ducts (in Amphibians), or special posterior derivatives of the latter.

URINOGENITAL DUCTS.

	Cyclostomata.	Ganoids and Teleosteans.	Elasmobranchs.	Amphibians.	Amniota.
A. Pronephros.	Persistent in hag (?).	Embryonic only.	A slight portion persists at origin of I.*b*. So in Dipnoi.	A slight portion persists at origin of I.*b*.	
B. Mesonephros.	At least most of adult's excretory organ in hag, all of it in lamprey.	Functional kidney.	Anterior part in the male is connected with the testes (epididymis, etc.). Anterior part in the female is atrophied or rudimentary. Posterior part becomes permanent kidney.		
B.1. (Metanephros).	O	O	O	O	Permanent kidney (derived from B).
I. Segmental or Archinephric duct.	Remains unsplit on each side.	Remains unsplit, or is perhaps partially split in Ganoids.	Splits into Wolffian and Müllerian ducts.		The Müllerian seems sometimes at least to have an independent origin.
I.*a*. Mesonephric or Wolffian duct.	O	O	Vas deferens of male; duct of anterior mesonephros (or Wolffian body) in the female.	Vas deferens and ureter in male; ureter in female.	Vas deferens in male, rudiment in female.
I.*b*. Müllerian duct.	O	O	Oviduct of female, rudiment in male.	Oviduct of female, rudiment in male.	Oviduct of female, rudiment in male.
(Ureter).	Segmental duct.	Segmental duct (?).	Outgrowth of I.*a*.	I.*a*.	Metanephric duct (from I.*a*.).
(Apertures).	Cloaca.	Anal and urinogenital separate in Ganoids and many Teleosteans; three openings in a few Teleosteans.	Cloaca; so in Dipnoi; three openings in Holocephali.	Cloaca.	Cloaca, except in Marsupial and Placental Mammals, in which anal and urinogenital openings are separate; three openings in females of the rat and a few others.

Supra-renal Bodies.—These are structures of unknown function, which occur in most Vertebrates near the reproductive organs and kidneys. They seem to have a double nature and origin : (*a*) a nervous part is derived from the sympathetic nervous system, and (*b*) a non-nervous part is derived from the anterior nephridia (pronephros or even part of the mesonephros), and from a degenerate anterior portion of the reproductive organs. But it does not seem to be certain that what are called supra-renal bodies are homologous throughout the series.

Reproductive System.—The ovaries and testes are developed from a ridge of the epithelium which lines the abdominal cavity.

The male elements or spermatozoa usually pass from the testes into efferent vessels which open on each side into a vas deferens or Wolffian duct.

The ova are shed from the ovaries into the body-cavity, but are usually more or less directly received by the Müllerian ducts or oviducts.

For some of the important exceptions, see Cyclostomata and Teleosteans.

Development.—A ripe ovum in the ovary is usually surrounded by a tunic of less successful cells. Tunic and ovum together form a "Graafian follicle," which bursts when the ovum is liberated.

Round the ovum are various membranes, notably a zona radiata traversed by fine pores, which give the membrane a striated appearance, and outside this a vitelline membrane of a firmer character. But these membranes are often transitory.

The formation of polar globules has been detected in the maturation of some Vertebrate ova, but not satisfactorily above Amphibians.

The ova are fertilised outside of the body in Cyclostomata, Ganoids, Teleosteans, Dipnoi, and tailless Amphibians, internally in the other Vertebrates.

Segmentation is total (holoblastic) in the ova of the lamprey, the sturgeon, the Amphibians, and all Mammals except the Monotremes. It is partial (meroblastic) in the ova of Elasmobranchs, Teleosteans, Reptiles, Birds, and Monotremes.

DIAGRAM XXIV.

URINOGENITAL SYSTEM.

Fig. 1 (after Hatschek) shows diagrammatically the primitive segmental ducts (*s. d.*) and their associated nephridia, *Ns.* nephrostoma, *M.* Malpighian tubule. The dotted lines indicate segments of the body.

Fig. 2 (after Balfour) shows for one side the primitive condition of the kidney in an Elasmobranch embryo :—*s. d.* the segmental duct, becoming split into Müllerian duct (*M. d.*) and Wolffian duct (*W. d.*), *t.* the segmental tubes or nephridia.

Fig. 3 (after Balfour) shows for one side the nature of the urinogenital organs in a female Elasmobranch :—*ov.* the ovary, *M. d.* the Müllerian duct or oviduct, *t.* the anterior mesonephros or Wolffian body, *W. d.* the Wolffian duct, *k.* the kidney formed from posterior nephridia, *u.* the ureter, *cl.* the cloaca.

Fig 4 (after Balfour) shows for one side the nature of the urinogenital organs in a male Elasmobranch :—*t.* the testis, *v. e.* the vasa efferentia, *t.* the anterior mesonephros or epididymis, *le.* a longitudinal vessel receiving the vasa efferentia, *W. d.* the Wolffian duct or vas deferens, *k.* the kidney formed from posterior nephridia, *u.* the ureter, *cl.* the cloaca, *M. d.* an anterior rudiment of the Müllerian duct.

Urinogenital System.

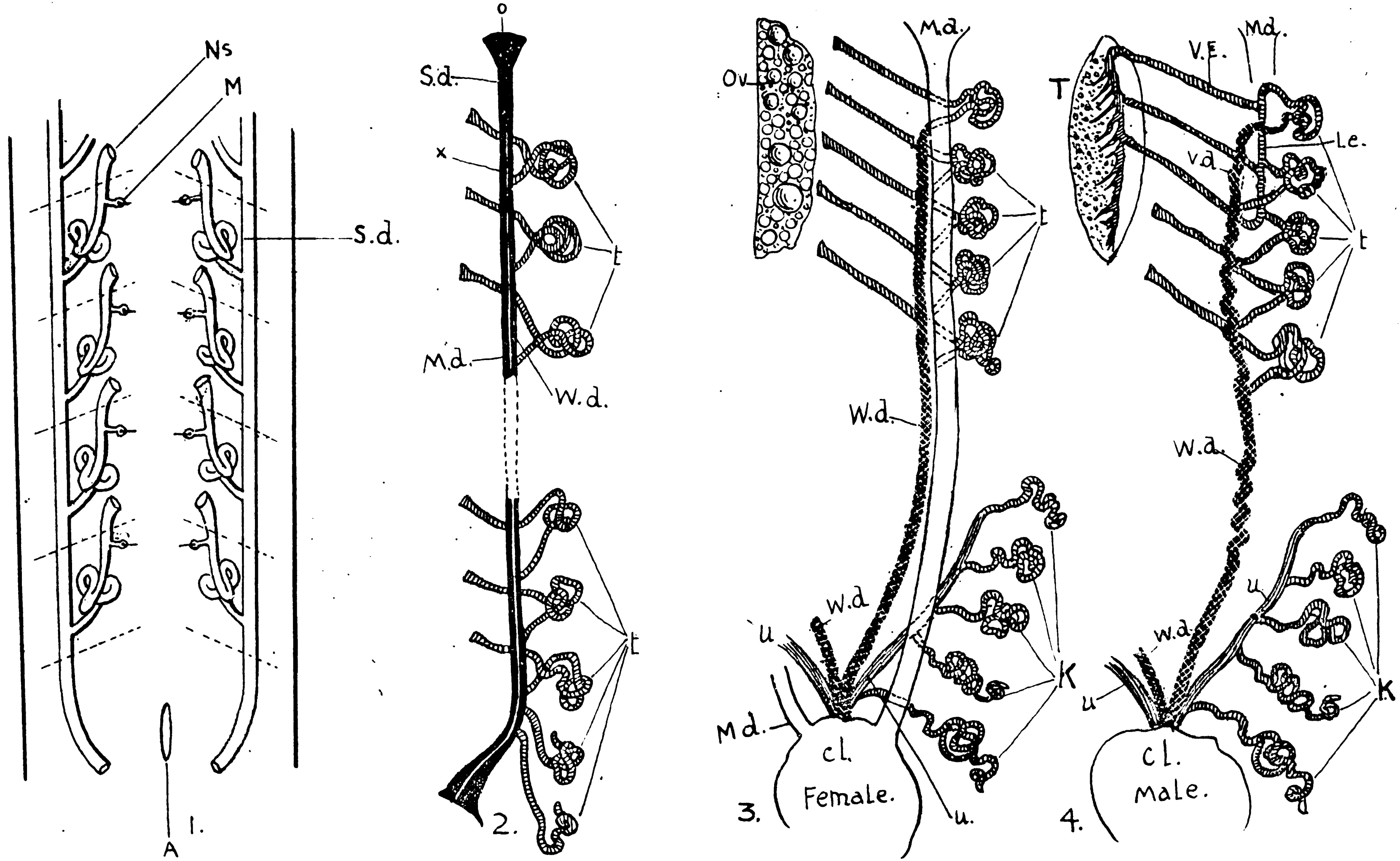


Diagram. XXIV.

A gastrula is formed, in part at least, by distinct invagination in the development of the lamprey, the sturgeon, and Amphibians; it is more modified in Teleosteans and Elasmobranchs whose ova have more yolk; it is much disguised in Sauropsida and Mammals.

Most Vertebrates lay eggs in which the young are hatched, and these animals are usually called oviparous, though all animals do of course produce eggs. In some sharks, a few Teleosteans, some tailed Amphibians, a few lizards and snakes, the young are hatched before they leave the body of the mother animal. To such the awkward term ovo-viviparous is sometimes applied, but there is no real distinction between this mode of birth and that called oviparous, and both may occur in one animal (*e.g.*, in the grass snake) in different conditions. In the placental Mammals, there is a close organic connection between the unborn young and the mother, and the parturition in this case is usually called viviparous. But this term is also objectionable, since all animals are in a sense viviparous.

CHAPTER XX.

CLASS CYCLOSTOMATA.

(SYN. MARSIPOBRANCHII.)

THE hag (*Myxine*), the lamprey (*Petromyzon*), and a few others like them, are so different from Fishes that it seems better to refer them to a distinct class. Unlike all higher Vertebrates which have distinct jaws (Gnathostomata), the hag and the lamprey (Cyclostomata) have round mouths in connection with which ordinary jaws are not distinctly developed. They are without paired fins and without scales; their respiratory system consists of 6–7 pairs of pouched gills, to which the term Marsipobranch refers. The skeleton remains wholly cartilaginous; the notochord persists unconstricted; the "nostril" is single; there is no conus arteriosus in the heart; no pancreas; no spleen; the segmental duct is unsplit.

FIRST TYPE OF CYCLOSTOMATA.

Myxine—The Hag.

The glutinous hag (*Myxine glutinosa*) is not uncommon off the coast of Scotland, N. England, Scandinavia, etc., living in the mud at depths of 40 to 300 fathoms. It often lies buried with only the nostril protruding from the mud, or it may swim about in search of prey. It eats the bait off the fisherman's long lines, and is said also to devour the cods and haddocks which have been caught on the hooks. According to some reports, the hag also attacks living

fishes, boring its way into them, but the evidence is not satisfactory. J. T. Cunningham discovered that the young animals are hermaphrodite, containing immature ova and ripe spermatozoa, while older forms produce ova only. Nansen has corroborated this, and calls the hag "protandric," *i.e.*, first male and then female. Of the development and early history nothing is known. They are said to spawn in late autumn.

Form.—The body is eel-like, and measures about fifteen inches when full-grown. There is a slight median fin around the tail; beside the mouth and nostrils are four pairs of barbules or tentacles. There are no paired fins.

The Skin is scaleless, and rich in goblet cells which secrete so much mucus that the ancients said the hag "could turn water into glue." There is a double row of glandular pits on each side of the ventral surface along the entire length of the animal. Each opens by a distinct pore.

Muscular System.—The muscle-segments or myomeres are to some extent traceable. Working the rasping teeth is a powerful muscular structure or "tongue."

The Skeleton is wholly cartilaginous. The notochord persists unsegmented within a firm sheath, the skull is a simple unroofed trough, jaws are not distinctly developed, there is little trace of the complicated basket-work of cartilage which supports the gill-pouches in the lamprey, but the tongue, the barbules, etc., are supported by cartilaginous rods. The end of the notochord in the tail is quite straight (protocercal or diphycercal).

Nervous System.—The brain has the usual parts, but is small and simple; the fore-brain seems to agree with that of Ganoids and Teleosteans in having a non-nervous roof. The spinal cord is somewhat flattened. Throughout at least a portion of the cord there are two posterior roots for each anterior root. The union of anterior and posterior roots is only partial, and there is no sympathetic system.

The eye is degenerate (*e.g.*, without a lens or iris), and is hidden beneath the skin; the ear has only one semi-circular canal; the single nasal sac opens dorsally at the apex of the head, and communicates posteriorly with the pharynx by a naso-palatine duct. The absence of sensory structures in

the skin, and the degeneracy of the eye may be associated with the hag's mode of life.

Alimentary System.—The mouth is suctorial. There is a median tooth above, and two rows of teeth are borne on each side of the muscular tongue. These teeth are "horny," but sharp. Into the mouth, just in front of a fringed velum which separates it from the pharynx, the nasal sac opens. Thus water passes from the nostril into the pharynx. It may be, as Beard suggests, that this passage is a persistent "old mouth." From the gullet open six respiratory pouches, each of which has an efferent tube, but the six efferent tubes of each side have a common exhalent orifice. The gut is straight and uniform, with longitudinal ridges internally, with a two-lobed liver and a gall-bladder, but without the usual pancreas.

Respiratory System.—Water enters by the nasal sac, passes into the pharynx, down the gullet, into the six pairs of respiratory pouches, out by their efferent tubes at a single aperture on each side. The respiratory pouches have much plaited internal walls, on which the blood is exposed.

Vascular System.—The blood contains nucleated red-corpuscles. It is collected from the body in anterior and posterior cardinals, passes through a sinus venosus into the auricle of the heart, thence to the ventricle, thence along a ventral aorta which gives off arches to the respiratory pouches. From these the purified blood passes dorsalwards in efferent branchial vessels, which unite posteriorly to form the dorsal aorta, while from the most anterior a branch goes to the head.

Excretory System.—The segmental or archinephric ducts remain unsplit, and the kidney or nephridial system is represented by a series of small segmental tubules attached to the ducts. According to some the pronephros or fore-kidney persists, though apart from the functional mesonephros; according to others it disappears. The segmental ducts are said to end much in the same way as they do in the lamprey.

Reproductive System.—*Myxine* is hermaphrodite, but the ova and spermatozoa are formed at different periods in its life. The reproductive organ is simple, unpaired, and moored by a median dorsal mesentery. Owing to the large

size of the ova the ovary is very conspicuous in full-grown forms. When the ova are freed from the ovary they pass into the body-cavity. Each has an oval horny case, with knobbed processes at each end. By these they become entangled together. There are no genital ducts, and the expulsion of the products requires to be investigated. The development is still unknown.

Besides *Myxine glutinosa*, two other species are known, one from Japan, another from the Magellan Straits. The genus *Bdellostoma*, from Southern Seas (off the Cape of Good Hope, etc.), is nearly allied; it has six or more gill-pouches which open apart from one another.

Second Type of Cyclostomata.

Petromyzon—The Lamprey.

There are three British lampreys, the sea lamprey (*Petromyzon marinus*) over three feet in length, the river lampern (*P. fluviatilis*) nearly two feet long, and the small lampern, or "stone-grig" (*P. branchialis* or *planeri*). They eat worms, small crustaceans, insect larvæ, dead animals, etc., but they also fix themselves to living fishes and scrape holes in their skin. As their names suggest, they also attach themselves firmly to stones, and some draw these together into nests.

The spawning takes place in spring, usually far up rivers. Some observers say that the adults die soon after reproduction. The young are in many ways unlike the parents, and pass through a metamorphosis. To the larvæ before metamorphosis the old name *Ammocœtes* is often applied.

Form.—The body is eel-like. There are two unpaired dorsal fins, and another round the tail. Two ridges, one on each side of the anus, Dohrn compares to rudimentary pelvic fins. Otherwise, there is no trace of limbs.

The *Skin* is scaleless, slimy, and pigmented. Its structure, like that of *Myxine*, is complex. Sensory structures occur on the head and along the sides.

Muscular System.—The muscle-segments are well-marked. The suctorial mouth and the rasping tongue are very muscular.

The *Skeleton* is wholly cartilaginous. The notochord persists unsegmented, but its firm sheath forms rudimentary neural arches. The skull is imperfectly roofed. There are no distinct jaws, but a cartilaginous ring supports the lips of the mouth. There is a complex basket-work around the gill-pouches, and it is likely that its elements correspond to visceral arches. Fin-rays support the dorsal and caudal fins, and other skeletal parts occur about the "tongue." The caudal end of the notochord is quite straight.

Nervous System.—The brain has the usual parts, but is small and simple; the roof of the fore-brain is composed of non-nervous epithelium; there is a distinct pineal body; the oral part of the hypophysis is developed from in front of the mouth, in close connection with the involution of epiblast which forms the nostril. The spinal cord is flattened; the anterior and posterior roots of the spinal nerves do not unite; there is no sympathetic system.

Though the larva sometimes receives the name of "nine-eyes"—which expresses a popular estimate of the branchial apertures—it is blind, for the eyes are rudimentary and hidden. In the adult they are on the surface, and fairly well-developed. The ear has only two semi-circular canals instead of the usual three. The single nasal sac does not open posteriorly into the mouth as it does in *Myxine*; though prolonged backwards it ends blindly. Its external opening is at first ventral, but is shunted dorsally.

Alimentary System.—The oral funnel, at the base of which the mouth lies, has numerous internal teeth. It is applied to the lamprey's victim, and adheres like a vacuum sucker; the toothed "tongue" works like a piston; both flesh and blood are thus obtained. From the floor of the pharynx a groove is constricted off, which is apparently homologous with the thyroid of higher Vertebrates.

From the gullet of the young larva seven gill-pouches open directly to the exterior; but in the adult this gullet becomes wholly a respiratory tube. It forms a *cul-de-sac*, opening anteriorly into the gullet of the adult, which is a new structure. At the junction of the respiratory tube with the gullet of the adult, lie two flaps or vela.

The rest of the gut is straight and simple, with a single-lobed liver, but without a pancreas. There is a slight fold

in the intestine which may be compared with the spiral valve of Elasmobranchs.

Respiratory System.—Seven gill-pouches with plaited walls open directly to the exterior on each side, and communicate indirectly with the gullet as already described.

When the lamprey is sucking a victim, and perhaps at other times, water passes in as well as out by the external openings of the gill-pouches. In the larva there is an eighth most anterior cleft which does not open to the surface. It corresponds to the spiracle of Elasmobranchs.

The *Vascular System* is essentially the same as in the hag. The red blood-cells are biconcave, circular, nucleated discs.

Excretory System.—There are two elongated kidneys (mesonephros), each with a wide ureter. The ureters open terminally into a urinogenital sinus, the external aperture of which lies behind the anus and in the same depression.

Reproductive System.—The sexes are separate. The reproductive organ is elongated, unpaired, and moored by a median dorsal mesentery. There are no genital ducts. The ova and spermatozoa are liberated into the body-cavity, and seem to pass by two abdominal pores into the urinogenital sinus, and thence to the exterior.

Development of P. planeri.—In the ripe ovum, which has a considerable quantity of yolk, the nuclear substance of the germinal vesicle is expanded like a cup at the "animal pole," forming the so-called "pole-plasma." Outside of this is a clear cupola which several spermatozoa may enter, though only one really penetrates into the egg. After a spermatozoon has begun to make its way inwards, two polar bodies are formed. The elements of the sperm-nucleus combine as usual in an intimate manner with those of the reduced nucleus of the ovum, and a segmentation-nucleus is formed about three hours after fertilisation.

Segmentation is total, but slightly unequal owing to the yolk; a blastosphere results which is invaginated into a gastrula. The blastopore or mouth of the gastrula persists as the anus of the animal, and there is never a neurenteric canal.

The formation of the central nervous system is peculiar, for the sides of the epiblastic infolding remain in contact instead of forming an open medullary canal.

In the head region, where the gut is not surrounded by yolk-cells, the mesoblast is formed from hollow folds in "enterocœlic" fashion; but in the trunk region the cushions of hypoblastic yolk-cells change gradually into mesoblast, and acquire a cœlome-cavity in "schizocœlic" fashion. Thus the two main ways in which a body-cavity arises, (*a*) from cœlome-pouches of the archenteron, (*b*) from a splitting of the solid mesoblast rudiments, are here combined.

DIAGRAM XXV.

CYCLOSTOMATA.

The figure named *Lamprey* (after Nuhn) shows from the ventral surface the seven gill-pouches (*g. p.*), opening directly to the exterior (*g. a.*), opening internally into a respiratory tube (*r. t.*), which lies ventral to the gullet. The dotted lines (*g.*) indicate the posterior continuation of the gullet, which is hidden anteriorly by the respiratory tube. The horny teeth (*t.*) in the mouth are shown.

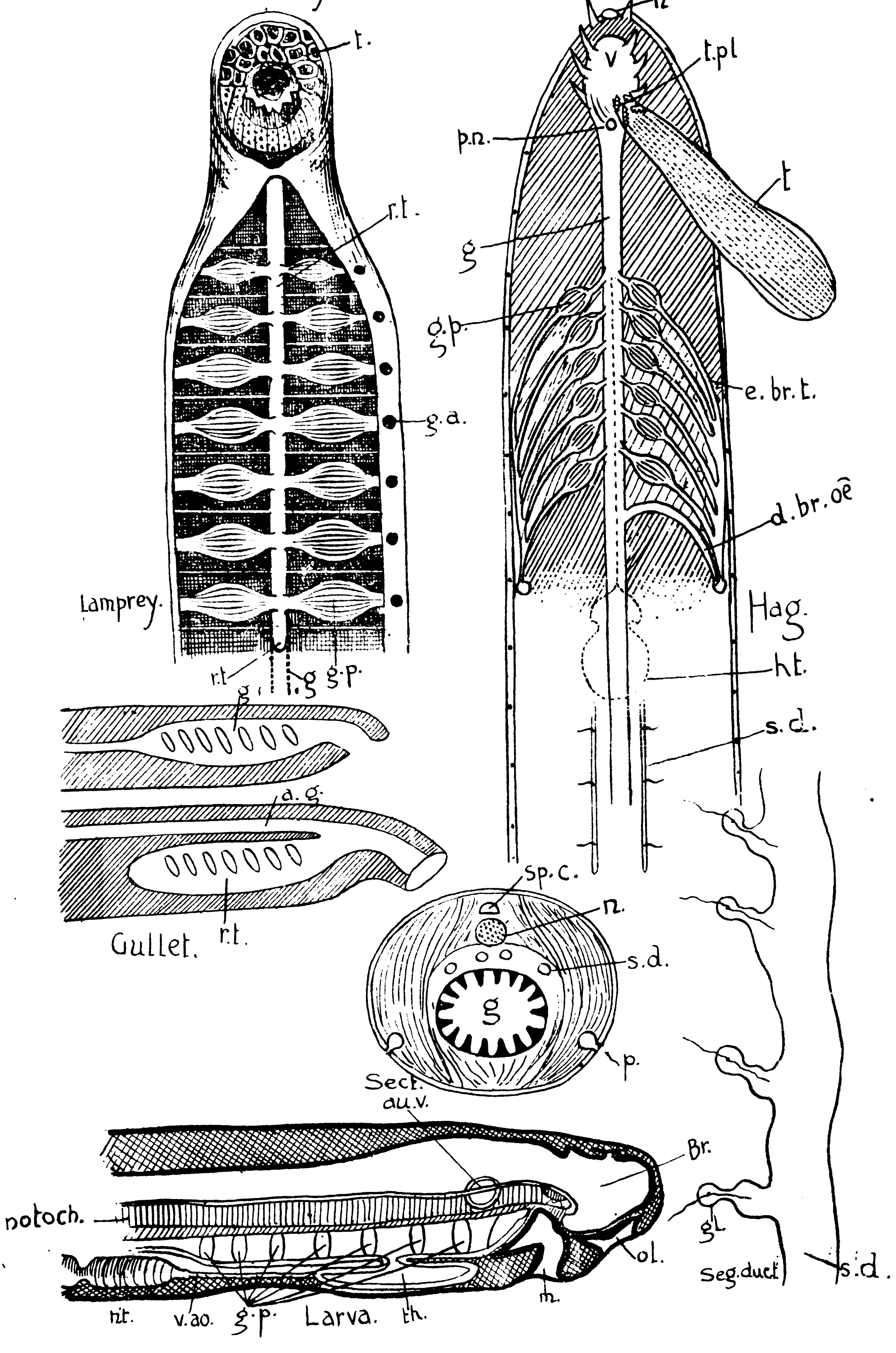
The figures named *Gullet* (after Wiedersheim) show the relation of the gullet and the respiratory tube in the lamprey. The upper figure refers to a larva in which there is no distinction between gullet and respiratory tube. The lower figure refers to a metamorphosed larva, in which the respiratory tube (*r. t.*) is distinct from the dorsal gullet (*d. g.*). At the foot of the page (*larva*) is a longitudinal section of a larval lamprey (after Balfour). The invagination forming the mouth (*m.*), the invagination forming the nostril (*ol.*), the gill-pouches (*g. p.*), the ventral constriction which forms the thyroid (*th.*), the heart (*ht.*), the ventral aorta (*v. ao.*), the notochord (*notoch.*), the brain (*br.*), the auditory vesicle (*au. v.*), are shown.

The figure named *Hag*, represents diagrammatically some of the structures of *Myxine*:—The nostril (*n.*), the posterior opening into the mouth (*p. n.*), the tongue muscle (*t.*) thrown to the side, the tooth-plates (*t. pl.*), the gullet (*g.*), the gill-pouches (*g. p.*), the efferent branchial tubes (*e. br. t.*), the convergence of these tubes to a single aperture on each side, an unpaired duct from the gullet to the aperture on the left side (*d. br. œ.*), the position of the heart (*ht.*), the anterior ends of the segmental ducts (*s. d.*).

Sect. is a diagrammatic section of the hag in the region behind the heart, showing :—The spinal cord (*sp. c.*), the notochord (*n.*), the lateral muscles, the gut (*g.*) with internal ridges, the segmental ducts (*s. d.*), with an artery and a vein between them, the pores (*p.*) of the lateral glands.

The figure named *Seg. duct* (from Gegenbaur, after Müller), shows a magnified part of the segmental duct (*s. d.*), with lateral nephridia, and associated blood-vessels (*gl.*).

Cyclostomata.



The time between fertilisation and the hatching of the larva, or *Ammocœtes*, varies with the temperature, being seventeen days in North Germany, but only eight at Naples.

The larvæ live wallowing in the sand or mud of streams, and feed on minute animals. Those of *P. planeri* are so unlike the adults that they were once referred to a distinct genus *Ammocœtes*, and though a Strassburg fisherman, Baldner, is said to have discovered their true nature about 200 years ago, the fact was overlooked until August Müller traced the metamorphosis in 1856. In the small lampern the change to the adult state is sometimes postponed until the autumn of the fourth or fifth year, when it completes itself rapidly. Less is known about the metamorphosis of the other species.

In the *Ammocœtes* or larva before metamorphosis the head is small; the dorsal fin is continuous, the upper lip is semi-circular, the lower lip is small and separate; the mouth is toothless, and not suctorial; the brain is long and narrow; the eyes are half-made, and hidden beneath the skin; the future gullet, as distinguished from the respiratory tube, is not yet developed.

Lampreys are distributed in the rivers and seas of north and south temperate regions. They are often used as food. Besides *Petromyzon* there are several related genera, *e.g.*, *Mordacia* and *Geotria*, from the coasts of Chili and Australia, and *Ichthyomyzon*, from the west coast of N. America. Certain structures called "conodonts" from very ancient (Silurian) strata are interpreted by some as teeth of lampreys or hags.

CYCLOSTOMATA.

HAG (*Myxine*).	LAMPREY (*Petromyzon*).
Exclusively marine.	In rivers and seas.
The fin is confined to the tail.	Two unpaired dorsal fins.
Numerous large glands in the complex, slimy skin.	Sensory structures in the complex, slimy, pigmented skin.
Mouth with barbules, no lips, few teeth.	No barbules, but lips, and many teeth.
Skull without any roof.	Skull very imperfectly roofed.
Skeletal system less developed than in the lamprey.	Hints of vertebral arches.
	Cartilaginous basket-work around gullet.
Eyes hidden and rudimentary.	Eyes hidden and retarded in the larva, exposed and complete in adult.
Ear with one semi-circular canal.	Ear with two semi-circular canals.
Nasal sac opens posteriorly into the pharynx.	Nasal sac ends blindly.
Six pairs of gill-pouches, opening directly into the gullet, less directly to the exterior.	Seven pairs of gill-pouches, opening directly to the exterior, less directly into the adult gullet.
Longitudinal ridges in the intestine.	A slight spiral fold in the intestine.
Ova large and oval, with attaching threads.	Ova small and circular.
(Development unknown).	Development with metamorphosis.

CHAPTER XXI.

Class Pisces. Fishes.

General Survey.

By the exclusion of the lancelet and the Cyclostomata, the class of Pisces has been made more homogeneous.

There are four orders :—

(4) Bony or Modern fishes,—Teleostei, such as Cod, Flounder, Salmon, Herring, Eel.

(3) Ganoid fishes,—Ganoidei, such as Sturgeon (*Acipenser*) and Bony-Pike (*Lepidosteus*).

(2) Mud-fishes or Double Breathers,—Dipnoi, *Ceratodus* and *Protopterus.*

(1) Cartilaginous fishes or Elasmobranchii, such as Skates and Sharks.

With the Elasmobranchs may be ranked the Holocephali, including *Chimæra* and *Callorhynchus.*

General Characters.

Fishes are aquatic Vertebrates, breathing by gills the oxygen dissolved in the water. In Dipnoi a single or double outgrowth from the gut—the air- or swim-bladder—is used as a lung. The same structure is present in Ganoids and in most Teleosteans, but usually serves solely as a hydrostatic organ, though sometimes of some slight usefulness in respiration.

Two pairs of limbs are almost always present, as paired fins supported by fin-rays. Fingers and toes begin with Amphibians. The unpaired fins which fringe the body are also supported by rays.

There are two great types of paired fins. In Dipnoi and

some extinct forms the fin has a central segmented axis, from which, in *Ceratodus* for instance, two series of lateral fin-rays arise. This type is called an archipterygium. In Elasmobranchs and other fishes the fin rays radiate outwards from several basal pieces, and there is no median axis. This type is called an icthyopterygium. It is not certain which type is the more primitive.

The skin almost always bears many scales, in great part due to the dermis. They vary greatly in form and texture. The skin also bears lateral sense-organs. Its glandular cells are not compacted into glands. The dermis is not muscular. In eels and electric fishes the scales are suppressed, and in some other cases they are rudimentary.

The heart is two-chambered, consisting of an auricle which receives impure blood from the body, and a ventricle which drives it by a ventral aorta to the gills, whence the conditions of blood-pressure cause the purified blood to flow to the head, and by a dorsal aorta to the body. In addition to the two essential chambers of the heart, there is a sinus venosus which serves as a porch to the auricle, and there often is a muscular conus arteriosus in front of the ventricle, or a bulbus arteriosus at the base of the ventral aorta. There is no vein which exactly corresponds to what is known from Amphibians onwards as the inferior vena cava. In Dipnoi the auricle of the heart is divided into two, and the circulation is in some respects peculiar.

There is no distinct indication of an outgrowth from the hind end of the gut comparable to that which forms the bladder of Amphibians, and the allantois of higher Vertebrates.

Most Fishes lay eggs which are fertilised in the water.

Life of Fishes.—A fish swims by lateral strokes of its tail and body, as a boat is propelled by an oar from the stern. The paired fins help it in ascending or descending, in steering and balancing. In a few cases, as in the climbing perch and *Periophthalmus*, the fore-fins are used for scrambling.

The characteristic form of the body, as seen in herring or trout, is an elongated laterally compressed spindle, thinning off behind like a wedge. It is evident that this form is well adapted for rapid progression through the water. Flat-fishes, whether flattened from above downwards like the

skate, or from side to side like the plaice and sole, usually live more or less on the bottom; eel-like forms often wallow in the mud, or creep in and out of crevices; globe-fishes, like *Diodon* and *Tetrodon*, often float passively. There are many strange fishes, such as the sea-horses (*e.g.*, *Hippocampus*), which play among the sea-weeds in warm seas. Some of the deep-sea fishes are very quaint.

The colours of Fishes are often very bright. They depend partly on pigments in the cells of the skin, partly on the physical structure of the scales. In many cases the colours of the male are brighter than those of his mate, witness the gemmeous dragonet (*Callionymus lyra*) and the stickleback (*Gasterosteus*), and this is especially true at the breeding season. The colours of many fishes change not a little in harmony with their surroundings. In the plaice and some others the change is rapid. Surrounding colour affects the eye, the influence passes from eye to brain, and from the brain down the sympathetic nervous system, thence by peripheral nerves to the skin, where the size of the amœba-like pigment-cells is affected. In shallow and clear water this power of colour-change may be of much protective value, but it seems likely that this has been exaggerated. In soles, flounders, plaice, and other "flat-fish," which in adult life lie or swim on one side, only the exposed surface is pigmented, the hidden side being white. It has been shown by J. T. Cunningham that an artificial illumination of the lower side induces the development of pigment, therefore we may say that the normal whiteness of this side is somehow due to the absence of light stimulus. An appreciation of the protective value of this difference of colouring demands careful attention to the habits and habitat of these fishes, to the nature of the light in which they live, and to the enemies which are likely to attack them.

The food of Fishes is very diverse—from Protozoa to Cetaceans. Sharks and many others are voraciously carnivorous, many engulf worms, crustaceans, insects, molluscs, or other fishes, others browse on sea-weeds, or swallow mud for the sake of the living and dead organisms which it contains. Their appetite is often enormous, and cases are known (*e.g.*, *Chiasmodon niger*), where a fish has swallowed another larger than its own normal size.

The sexes are separate, except in *Chrysophrys* and *Serranus*, two hermaphrodite bony fishes, or when abnormal hermaphroditism occurs, as in herring and mackerel. In many cases the males are smaller, brighter, and less numerous than the females. Courtship is illustrated by the sticklebacks (*Gasterosteus*, etc.), the paradise-fish (*Macropodus*), and others, while the bent lower jaw of the male salmon reminds us that some male fishes fight with their rivals.

Most Fishes lay eggs which are fertilised and develop outside of the body. They may be extruded on gravelly ground or sown broadcast in the water. Sturgeon, salmon, and some others ascend rivers for spawning purposes, while the eels descend to the sea. In the case of trout, Barfurth has observed that the absence of suitable spawning ground may cause the fish to retain its ova. This results in ovarian disease and in an inferior brood next season, a fact which should be compared with what Hertwig has observed in regard to Echinoderms, that ova which are retained beyond the normal period become over-ripe and pathological. Except in Elasmobranchs the ova are relatively small, and large numbers are usually laid at once. In Elasmobranchs, the egg is large, and in the oviparous genera it is enclosed in a "horny" sheath, familiarly illustrated by the mermaid's purse of the skate.

Most sharks and a few Teleosteans are viviparous, the eggs being hatched within the body of the mother,—in the lower part of the oviduct in sharks, in the ovary in Teleosteans. In two of the viviparous sharks (*Mustelus lævis* and *Carcharias glaucus*), there is an interesting union between the yolk-sac and the wall of the oviduct, which should be compared with a similar occurrence in two lizards, and with the placenta of most Mammals.

As to fertilisation, the usual process is that the male deposits spermatozoa or "milt" upon the laid eggs or "spawn," but fertilisation is of course internal when the eggs are enveloped in a firm sheath, or when they are hatched within the mother.

Most Fishes have a great number of offspring, and parental care is proportionately little. Moreover, the conditions of their life are not suited for the development of that virtue.

When it is exhibited it is usually by the males, witness the sea-horse (*Hippocampus*) and the pipe-fish (*Syngnathus*), which hatch the eggs in external pouches, and "the male of some species of *Arius*, who carries the ova about with him in his capacious pharynx." The female of *Aspredo* carries the eggs on the under surface of the body until they are hatched, much in the same way as the Surinam toad bears her progeny on her back, while in *Solenostoma* a pouch for the eggs is formed by the ventral fins and skin. At least a dozen kinds of fishes make nests, of which the most familiar illustration is that of the male stickleback, who twines grass stems and water-weeds together, glueing them by mucous threads exuded as semi-pathological products from the kidneys, which are compressed by the enlarged male organs.

Fishes have a less definite limit of growth than most other Vertebrates. Surroundings and nutrition affect their size and colour very markedly. Some marine forms, such as flounders, may survive being shifted to fresh water, while others, such as salmon and sturgeon, pass from sea to rivers at spawning time. But most are sensitive to changes of medium. Many can endure prolonged fasting, and some may survive being frozen stiff. Lowered temperature may induce torpor, as seen in the winter sleep of the pike, while in the dry season of hot countries the mud-fishes, the Siluroids and others, encyst themselves in the mud and remain for a long time in a state of "latent life."

Commensalism is illustrated by some small fishes which shelter inside large sea-anemones, and by *Fierasfer*, which goes in and out of sea-cucumbers and medusæ. On the outside or about the gills of Fishes parasitic Crustaceans, fish-lice, are often found, various Flukes are also common external parasites, and many Cestodes in bladderworm or tapeworm stage infest the viscera. The immature stages of *Bothriocephalus latus* occur in pike and burbot; a remarkable hydroid (*Polypodium*) is parasitic on the eggs of a sturgeon; the young of the fresh-water mussel are temporarily parasitic on the stickleback.

There are about 2300 fresh-water species of Fishes—three or four of these are Dipnoi, about thirty are Ganoids, and the rest Teleosteans. Among marine Fishes, about 3500 species frequent the coasts, rarely descending below 300 fathoms; a

much smaller number, including many sharks, live and usually breed in the open sea; about 100 genera have been recorded from the great depths. In regard to the latter, Günther has shown that in fishes from a depth of 80–200 fathoms the eyes are larger than usual, as if to make most of the scanty light; beyond the 200 fathom line small-eyed forms occur with highly developed organs of touch, and large-eyed forms which have no such organs, but seem to follow the gleams of phosphorescence; finally, in the greatest depths blind fishes occur with rudimentary eyes. Many of these abyssal fishes are phosphorescent; the colouring is usually simple, most being blackish or silvery; the skin exudes much mucus; the skeleton tends to be light and brittle; the forms are often very quaint; the diet is necessarily carnivorous.

The Skate (*Raja*)—a type of Fishes, especially of the order Elasmobranchii.

Various species of *Raja*—the skate proper (*R. batis*), the thornback (*R. clavata*), and the ray (*R. maculata*)—are common off the coast of Britain. They differ only in colour and minute details. They are comparatively sluggish but undoubtedly voracious fishes, and live along the bottom at considerable depths.

Form.—The body is flattened from above downwards or dorso-ventrally, unlike that of the bony flat-fishes such as plaice and flounder, which are flattened from side to side. The skate rests on its ventral surface, the flounder on its side. No one who has looked at a skate will require any description of the triangular snout, the broad pectoral fins, the long tail with small unpaired fins; but the following external characters should be verified. On the dorsal surface the skin is pigmented and studded with skin-teeth; on the top of the skull there are two unroofed areas or fontanelles, and there are numerous jointed rays in the pectoral fins. Behind the lidless eyes are the spiracles—the first of the obvious gill-slits, opening dorsally, containing a rudimentary gill, and communicating posteriorly with the mouth-cavity. On the ventral surface, are seen the sensitive mucus-canals extending over the skin, the transverse mouth and the

nostrils incompletely separated therefrom as if in double hare-lip, the five pairs of gill apertures, the cloacal aperture and two abdominal pores beside it. We may feel the pectoral and pelvic girdles supporting the fore and hind fins, or limbs. In the male, the latter have "claspers" which are inserted into the cloaca of a female during copulation.

Skin.—On the dorsal pigmented surface there are many "skin-teeth," or "dermal denticles," or "placoid scales." Each is based in bone, cored with dentine or ivory, tipped with enamel, the latter being due to the ectoderm (epidermis), the rest to the mesoderm (dermis or cutis) of the skin, the whole being originally a skin-papilla. On the ventral unpigmented surface, numerous mucous canals are readily seen, and there are also some on the dorsal aspect. These jelly-tubes have a sensory function. Most of the slime which exudes on the surface comes from glandular goblet-cells in the skin.

Muscular System.—In the posterior part of the body and in the tail, the segmental arrangement of the muscles may be recognised. The large muscles which work the jaws are noteworthy. In the tail-region, Prof. Cossar Ewart has demonstrated a rudimentary electric organ in *Raja batis* and *R. clavata.*

Electric organs are best developed in two Teleostean fishes—a S. American eel (*Gymnotus*) and an African Siluroid (*Malapterurus*), and in the Elasmobranch *Torpedo.* In *Gymnotus* they lie ventrally along the tail, in *Malapterurus* they extend as a sheath around the body, in *Torpedo* they lie on each side of the head, between the gills and the anterior part of the pectoral fin. In other cases where they are slightly developed, both in Elasmobranchs and Teleosteans, they lie in the tail. Separated from one another by connective tissue partitions, are numerous "electric plates," which consist of strangely modified muscle-substance and numerous nerve-endings. The electric discharge is very distinct in the three forms noted above, and is controlled in some measure at least by the will of the animal.

The Skeleton is for the most part gristly, but here and there ossification has taken place, as a crust over many parts, but more deeply in the vertebral bodies, in the teeth, and in the tooth-like scales.

The notochord has an endodermic origin; the enamel tips of the teeth and skin-teeth are ectodermic; otherwise the entire skeleton is derived from the mesoderm.

The vertebral column consists of an anterior plate not divided into vertebræ, and of a posterior series of distinct vertebral bodies. Each of these consists of a biconcave or amphicœlous centrum. From each side of the centrum a transverse process projects backwards, and bears a minute hint of a rib. From the dorsal surface of each centrum rise two neural processes, which arch upwards on each side of the spinal cord; the arch is continued upwards in inter-neural plates which meet a neural spine on the top. In the caudal vertebræ, what seem to be the transverse processes are directed downwards, to form a hæmal arch enclosing an artery and a vein. In the spaces between the vertebræ lie the gelatinous remains of the notochord. The vertebral column develops from the mesodermic sheath of the notochord.

The skull is a cartilaginous case, with a spacious cavity for the brain, a large posterior aperture or foramen magnum through which the spinal cord passes, a large ear-capsule on each side posteriorly, a similar nose-capsule on each side anteriorly, a long snout or rostrum projecting in front, two incomplete regions or fontanelles on the roof. The skull of the skate develops from (*a*) a pair of parachordal plates lying on each side of the anterior end of the notochord, (*b*) from another pair of trabecular plates lying further forward. These coalesce as the floor of the brain-case, and extend upwards and around the brain, being aided (*c*) by the ear-capsules and nose-capsules. Furthermore, the skull is connected ventrally with a number of visceral arches. Compared with the skull of a cod or of a higher Vertebrate, that of a skate is simple; it is not ossified, nor divided into distinct regions, nor has it anything corresponding to the covering or membrane bones, which in higher animals are added to the original foundations of the skull, nor are the visceral arches in the skate directly implicated in forming the skull.

The arches are primitively supports for the wall of the anterior part of the food-canal, but at least two of them are much modified alike in position and function.

The upper jaw of the skate is a strong transverse bar, formed from the union of two palato-pterygo-quadrate cartilages. The lower jaw is a similar bar formed from the union of two Meckel's cartilages.

From the ear-capsule towards the articulation of upper and lower jaw there extends on each side a club-shaped cartilage known as the hyo-mandibular. Attached to this is a slender three-jointed rod—the hyoid.

Then follow five branchial arches, each primarily four-jointed, forming the framework of the gill-bearing region.

Of less importance are four labial cartilages about each nose-capsule, an antorbital cartilage uniting the nose-capsule with the end of the pectoral fin, and a spiracular cartilage supporting the rudimentary gill in the spiracle.

The shoulder girdle is a broad cartilaginous bar of double origin. It is fixed dorsally to the vertebral plate. Its dorsal region is distinguished as scapular, its ventral as coracoid. Its outer edge bears three facets, to which the three basal pieces of the pectoral fin are fixed.

Of these three basal pieces the anterior or propterygium and the posterior or metapterygium are large, the median or mesopterygium is small. All bear jointed fin-rays.

The hip-girdle is a smaller ventral bar, with two articulating facets, to the posterior of which the strong basal piece or metapterygium of the hind-limb is attached. From this, and from the anterior facet of the girdle, the jointed fin-rays proceed. The claspers of the males are closely connected with the hind limb, and have a very complex cartilaginous skeleton and an associated gland.

Nervous System.—The brain (see p. 378–81) has the following parts:—

(1) The fused cerebral hemispheres or prosencephalon, with a nervous roof, and without ventricles.

(2) The thalamencephalon or region of the optic thalami, with a thread-like pineal body above, infundibulum and pituitary body below, thinly roofed third ventricle within.

(3) The mesencephalon or mid-brain with the optic lobes above, the crura cerebri below, the iter passing between.

(4) The cerebellum with an anterior and a posterior lobe, both marked by ridges and grooves.

(5) The medulla oblongata, with thin vascular roof, with dorso-lateral extensions called "restiform bodies."

The region beneath the thalamencephalon bears (*a*) two ovoid inferior lobes, (*b*) the infundibulum which carries the pituitary body, and (*c*) the thin-walled three-lobed saccus vasculosus situated between the pituitary body and the inferior lobes.

The ten pairs of cranial nerves (see p. 381) are as usual:—

(1) The olfactory, issuing from the cerebral hemispheres, expanding at the nostrils into bulbs shaped like the heads of golf clubs.

(2) The optic, fusing in a chiasma as they cross after leaving the optic thalami.

(3) The oculomotor or ciliary, arising from the crura cerebri, supplying four of the muscles of the eye.

(4) The pathetic, arising from beneath the anterior sides of the cerebellum, supplying the superior oblique muscle of the eye.

(5) The trigeminal, arising from the medulla, and consisting (*a*) of a superficial ophthalmic or orbito-nasal to the sensory tubes of the snout, (*b*) a maxillary branch for the most part to anterior sensory tubes, (*c*) of a third division, the mandibular to both upper and lower jaws. Another nerve—the opthalmicus profundus—which sends branches to the eye-ball, the snout, etc., is referred by some to the oculomotor, by others to the trigeminal, and is regarded by others as an independent nerve.

(6) The slender abducens, arising along with the 5th and 7th, and supplying the external rectus muscle of the eye.

(7) The facial, arising along with the 5th, including, according to Prof. Cossar Ewart, (*a*) superficial ophthalmic, (*b*) buccal, (*c*) palatine, (*d*) hyo-mandibular. The name ophthalmic is applied, somewhat confusedly, to a branch of the fifth, a branch of the seventh, and to the ophthalmicus profundus.

(8) The auditory, arising under the 5th and 7th, from the medulla oblongata, innervating the ear.

(9) The glosso-pharyngeal, arising from the sides of the medulla oblongata, entering the auditory capsule, ending in connection with the first of the functional gill-slits.

(10) The vagus, arising by six ganglionated roots from the hind region of the medulla oblongata, innervating gills, stomach, heart, and other parts.

The spinal cord lies in the cartilaginous neural canal above the vertebral column, is divided by deep dorsal and ventral fissures, and gives off numerous spinal nerves, formed as usual from the union of dorsal (sensory) and ventral (motor) roots. The first sixteen or eighteen nerves form the brachial plexus, converging and uniting in a trunk which supplies the pectoral fin.

The sympathetic system consists of a longitudinal ganglionated cord along each side of the vertebral column. The ganglia of these cords are connected with the spinal nerves.

Sense-Organs.

(*a*) The Eyes (see p. 387). The iris has a beautifully fringed upper margin.

(*b*) The Ears (see p. 386). The vestibule is connected with the surface by a delicate canal—the aqueductus vestibuli—a remnant of the original invagination. Within the vestibule are calcareous otolithic particles surrounded by a jelly.

(*c*) The Nasal sacs are cup-like cavities with plaited walls.

(*d*) The Sensory tubes are best seen on the ventral surface, where they lie just under the skin, and open by minute pores. They seem to form a diffused tactile system.

Alimentary System.—The mouth is a transverse aperture; the teeth borne by the jaws are numerous, and those worn away in front are replaced by fresh teeth from behind; naso-buccal grooves connect the nostrils with the corners of the mouth; the spiracles or first gill-clefts, which open dorsally behind the eyes, communicate with the buccal cavity; from the gullet five gill-clefts open ventrally on each

side; the stomach lying rather to the left is bent upon itself; the large brownish liver is trilobed, and has an associated gall-bladder from which the bile-duct extends to the duodenum—the part of the gut immediately succeeding the stomach; the whitish pancreas lies in the duodenal loop between stomach and intestine, and its duct opens opposite the bile-duct; the intestine contains an internal spiral fold—a membrane which increases the absorptive surface; a small rectal gland of unknown significance is attached to the terminal or rectal portion of the gut; the end of the gullet and the anterior portion of the stomach and the rectum are supported by folds of peritoneum,—the membrane which lines the body-cavity,—the rest of the gut lies freely; into the terminal chamber or cloaca the rectum, the ureters, and the genital ducts all open; an abdominal pore opens on each side of the cloacal aperture.

Respiratory System.—The first apparent gill-clefts—the spiracles—open dorsally behind the eyes. Each contains a rudimentary gill, supported by a spiracular cartilage. Through the spiracles water may enter or leave the mouth.

There are five pairs of gill cavities, separated by partitions, and with ventral apertures. The first cavity is bounded anteriorly by the hyoid arch, posteriorly by the first branchial arch. The hyoid arch bears branchial filaments on its posterior surface; the first four branchial arches bear gill-filaments on both surfaces; the fifth branchial arch bears none. Each of the first four branchial arches bears a half gill on each side; thus, including the gill-filaments borne on the posterior side of the hyoid, there are four and a half gills. The absence of an operculum or gill-cover is obvious.

The anterior innominate artery or branch of the ventral aorta supplies the first half gill of the hyoid, and the two half gills borne by the first branchial. The posterior innominate artery supplies the gills borne by the second, third, and fourth branchial arches.

Circulatory System.—The impure blood from the body enters the heart by a bow-shaped sinus venosus, which leads into a large thin-walled auricle. Thence through a bivalved aperture the blood passes into a smaller muscular ventricle,

and from this it is driven through a contractile conus arteriosus, with three longitudinal rows of five valves, into the ventral aorta.

The ventral aorta gives off a pair of posterior innominate arteries, which take blood to the three posterior gills, and a pair of anterior innominate arteries which supply the anterior gill and the hyoid half gill on each side.

The purified blood passes from each half gill by an efferent branchial artery. To begin with there are nine of these on each side, but by union they are reduced to three efferent trunks which combine to form the dorsal aorta.

From the efferent branchial of the hyoid arch, a carotid arises, which divides into internal and external branches supplying the brain and head. From the first of the efferent trunks, a vertebral arises which supplies the brain and spinal cord.

The dorsal aorta gives off—(1) two brachials to the pectoral fins; (2) a cœliac to the stomach, duodenum, and liver; (3) a superior mesenteric to the intestine, pancreas, and spleen; (4) spermatic arteries to the reproductive organs; (5) an inferior mesenteric to the rectum; (6) renal arteries to the kidneys; (7) arteries to the pelvic fins. It ends in the caudal artery.

At each end of the bow-shaped sinus venosus, there is a pre-caval sinus. This receives venous blood as follows:—(*a*) from the head by a jugular vein, (*b*) from the liver by a hepatic sinus, which runs from one pre-caval sinus to the other like the string of the bow, (*c*) from a large posterior cardinal sinus (between the reproductive organs) by a cardinal vein on each side, (*d*) from the hind-fin by an epigastric, with which a brachial from the fore-limb unites anteriorly. The great cardinal sinus receives blood from the hind-limbs, the kidneys, and other posterior parts.

Blood passes into the liver (*a*) from the cœliac artery, and (*b*) by portal veins from the intestine (the hepatic portal system); blood leaves the liver by hepatic veins which enter the hepatic sinus.

Blood passes into the kidneys (*a*) from the renal arteries, and (*b*) by renal portal veins from the caudal, pelvic, and

lumbar regions (the renal portal system); blood leaves the kidneys by posterior cardinal veins, which enter the cardinal sinus.

Finally, be it noted that into the pre-caval sinus, there opens the lymphatic trunk, with nutritive fluid from the intestine.

The heart lies in a pericardial cavity, which is connected with the abdominal cavity by two fine canals.

The dark red spleen lies in the curve of the stomach. The red thyroid gland lies just in front of the anterior end of the ventral aorta. The whitish thymus gland is a paired structure lying dorsally above the gills.

Excretory System (see pp. 398–9).—The elongated, dark red kidneys lie posteriorly on each side of the vertebral column. They are developed from the hind part of the mesonephros. Several tubes from each kidney combine to form a ureter. The two ureters of the male open into the urinogenital sinus, whence the waste-products pass out by the cloaca; in the female they open into little bladders—the dilated ends of the Wolffian ducts, and thence by a common aperture into the cloaca.

The archinephric or segmental duct of each side divides into a Wolffian and a Müllerian duct. The Wolffian duct becomes in the male the vas deferens, in the female an unimportant mesonephric duct; the Müllerian duct becomes in the female the oviduct, and in the male a mere rudiment.

Reproductive System.—The male organs or testes lie on each side of the cardinal sinus, moored by a fold of peritoneum. The spermatozoa pass from each testis by vasa efferentia into the tube surrounded anteriorly by an epididymis. The tube of the epididymis is continued into the vas deferens, which is dilated posteriorly into a seminal vesicle and an adjacent sperm-sac. Finally, the two vasa deferentia open into the urinogenital sinus, through which the spermatozoa pass into the cloaca. In copulation, the complex "claspers" of the male are inserted into the cloaca of the female.

The female organs or ovaries lie on each side of the cardinal sinus, moored by a fold of peritoneum. In young skates they are exactly like the young testes, but in the adults they are covered with large Graafian follicles, each

DIAGRAM XXVI.

ELASMOBRANCHS.

The Fig. named *Skull* (after W. K. Parker) shows the snout and nasal capsules, with four pairs of labial cartilages (l^{1-4}), the antorbital cartilage (*a. o.*), the palato-pterygo-quadrate (*q. p. pt.*), Meckel's cartilage (*m. c.*), the first hypo-branchial ($h.\ br.^1$), the fifth hypo-branchial ($h.\ br.^5$), the cerato-hyal (*c. hy.*), the fifth pharyngo-branchial ($p.\ br.^5$).

The Fig. named *Egg-case* (after Günther) shows a mermaid's purse.

Brain shows the cerebral hemispheres (*c. h.*) and the olfactory nerves, the optic thalami (*thal.*), the optic lobes (*opt.*), the cerebellum (*cereb.*), the medulla oblongata (*m. o.*), the origin of the 2nd, 5th, and 10th nerves.

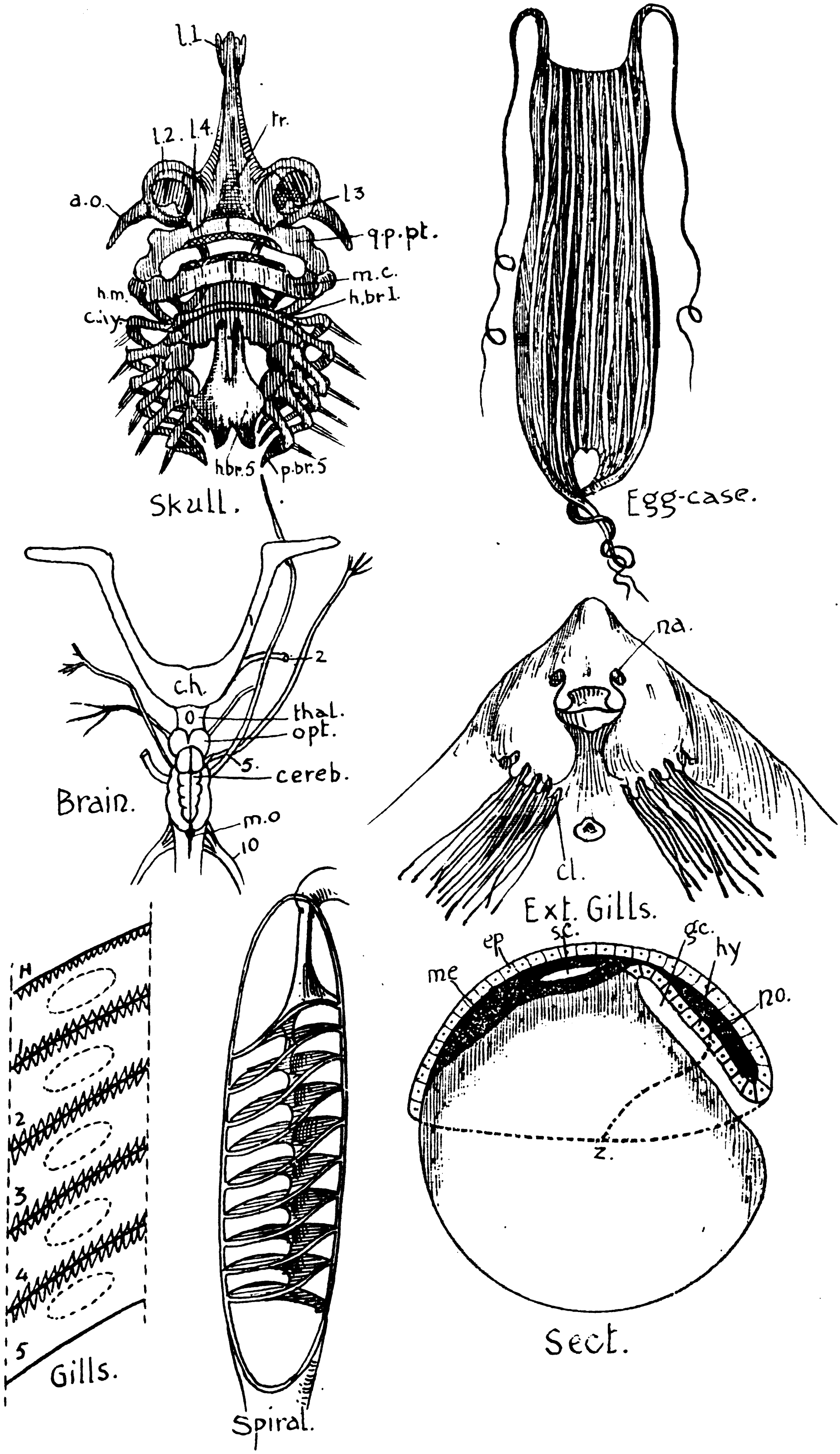
The Fig. *Ext. gills* (after W. K. Parker) shows the external gills on a young skate.

The disposition of the *Gills* is shown diagrammatically; *H.*, the hyoid arch with half a gill, 1–4, the first four branchial arches each with a gill, 5, the fifth arch without any.

Spiral (after Günther) shows the spiral fold in the large intestine.

Sect. (after J. T. Cunningham) represents a section of a segmented ovum :—*ep.* the epiblast; *hy.* the invaginated hypoblast; *me.* (dark) the mesoblast; *s. c.* the segmentation cavity; *g. c.* the gastrula cavity; *no.* (dark) the rudiment of the notochord; the dotted line (*z*) suggests how far the blastoderm has spread over the yolk.

Elasmobranchs.



Skull. Egg-case. Brain. Ext. Gills. Gills. Spiral. Sect.

containing an ovum. The ripe ova burst into the body-cavity, and enter the single aperture of the oviducts, which are united anteriorly. In the upper part of the oviduct the ovum is fertilised, in the middle part it is enclosed in a "mermaid's purse," secreted from a dilatation known as the oviducal gland. The lower or uterine portions of the oviducts open into the cloaca.

Development.—The ripe ovum which bursts from the ovary and passes into the oviduct is a large sphere of yolk, with the formative protoplasm concentrated at one pole. It seems that the nuclear division, usually associated with maturation, takes place at a very early stage. In the upper part of the oviduct the ovum is fertilised. As it descends it is surrounded by albuminous material, and by the four-cornered "mermaid's purse" secreted by the walls of the oviducal gland. This purse is composed of a horny substance allied to that of hair and hoof. Its corners are produced into long elastic tendrils, which may twine round sea-weed, and thus moor the egg. Rocked by the waves, the embryo develops, and the young skate leaves the purse at one end.

The segmentation is meroblastic, being confined to the disc of formative protoplasm. From the edge of the blastoderm, which results from the segmentation, some nuclei are formed in the outer part of the subjacent yolk. These yolk-nuclei afterwards share in the making of the embryo.

At the close of segmentation the blastoderm is a lens-shaped disc with two strata of cells. It is thicker at one end—where the embryo begins to be formed. Towards the other end, between the blastoderm and the yolk, lies a segmentation cavity.

At the embryonic end, the outer layer or epiblast undergoes a slight invagination, beginning to form the roof of the future gut, in other words establishing the hypoblast. This inflected arc of the blastoderm corresponds to the blastopore or mouth of the gastrula, which is much disguised by the presence of a large quantity of yolk. As the invagination proceeds, the segmentation-cavity is obliterated. The floor of the gut is formed from the yolk-nuclei.

Along the mid-dorsal line of the epiblast a medullary groove appears — the beginning of the central nervous system. Its sides afterwards arch towards one another, and meet to form a medullary canal. A posterior communication between this dorsal nervous tube above and the ventral alimentary tube persists for some time as the neurenteric canal.

The mesoblast arises as two lateral plates, one on each side of the medullary groove. The plates seem to arise as a pair of solid outgrowths from the wall of the gut. They are afterwards divided into segments. Between the mesoblast plates, along the mid-dorsal line of the gut, the notochord is established.

Besides the internal establishment and differentiation of layers, there are two important processes, (*a*) the growth of the blastoderm around the yolk, (*b*) the folding off of the embryo from the yolk. The yolk is thus enclosed in a yolk-sac, with which the embryo is finally connected only by a thin stalk—the umbilical cord. Through the canal of this cord nutriment is absorbed into the gut, and blood-vessels also effect the same result.

What the different layers form, and how the organs arise, may be safely inferred from the general conclusions stated elsewhere.

THE ORDERS OF FISHES.

Order I. ELASMOBRANCHII—Cartilaginous Fishes.

Synonyms. Selachii. Plagiostomata (with transverse ventral mouth).

Sharks and skates represent the two distinct types included in this order. They are voracious carnivorous fishes. The scales are "skin-teeth." There is no cover over the (5–7) gill-apertures; anterior to these there is often a spiracle, —the first gill-cleft with a rudimentary gill. The fins are large. The skeleton is mostly cartilaginous. The tail is asymmetrical or heterocercal. The mouth extends transversely on the under side of the head. The nostrils are also ventral. A spiral fold extends along the internal wall of the large intestine. Into the terminal chamber (or

cloaca) of the gut, the genital and urinary ducts also open. The ventricle of the heart has an anterior auxiliary region —a contractile conus arteriosus. The males are provided with copulatory modifications of the hind limb, known as claspers. Fertilisation is internal. The ova are few and large. Large egg-purses are common, but some Elasmobranchs are viviparous. The embryos have external gills.

Subdivisions.—The shark and the skate are types of two distinct sub-orders:—(1) the older *Selachoidei*, with approximately cylindrical bodies and lateral gill openings, as in shark and dog-fish; (2) the more modified *Batoidei*, with flattened bodies and ventral gill openings, as in skates or rays.

Special Forms.—*Mustelus*, *Carcharias*, *Squalus*, *Torpedo*, *Acanthias*, and others, are viviparous; *Raja*, *Scyllium*, *Cestracion*, and others, are oviparous. In two species of the genera first named, there is a placenta-like connection between the yolk-sac of the embryo and the uterus of the mother. *Zygæna* has a peculiar hammer-like head expansion; *Pristis* has the snout prolonged into a tooth-bearing saw; *Torpedo* has a powerful electric organ.

History.—The Elasmobranchs appear in the Upper Silurian, are very abundant from the Carboniferous onwards, but are now greatly outnumbered by the Bony Fishes. An increasing calcification of the axial skeleton is traceable through the ages, and in some of the ancient forms the exoskeleton was greatly developed, often including long spines or ichthyodorulites firmly fixed on the dorsal fins or on the neck. Among the most remarkable extinct genera is *Pleuracanthus*, from Carboniferous to lower Permian. It had a terminal mouth, a naked body, a continuous dorsal fin, a symmetrical tail, and pectoral fins with a serial arrangement of rays somewhat like that in *Ceratodus*. A Japanese shark *Chlamydoselachus*, allied to forms in the Devonian, is said to be the oldest living fish.

The Holocephali are represented by the sea-cat or *Chimæra* from northern seas, and *Callorhynchus* from the south. There is a fold or operculum covering the gill-clefts and leaving only one external opening on each side; the jaws are rigidly fixed to the cartilaginous skull; the skin is naked; the anus, the Müllerian and urinary ducts open separately. Otherwise the Holocephali resemble Elasmobranchs, and may be regarded as a sub-order.

Order II. Dipnoi.

The mud-fishes or double-breathers, including *Ceratodus* and *Protopterus*.

General Characters.—The body is covered with comparatively soft scales; the skeleton is in part cartilaginous;

the notochord persists unsegmented; the paired fins have a central axis; the tail is symmetrical (diphy- or proto-cercal); the fore-brain has a nervous roof; the nasal sacs open anteriorly just in front of the mouth and posteriorly within it; there is a cloaca, and a spiral valve in the intestine; there are abdominal pores; the swim-bladder acts as a single or double lung, and there are gills as well; the auricle is divided by a complete partition, and the ventricle by a slight one, which is continued into the large spirally twisted conus arteriosus; the Müllerian duct is developed.

Genera.—The genus *Ceratodus* is represented by two species in the rivers of Queensland, and by fossil remains from Triassic and reputed Permian strata. The living species frequent still rivers, feed on the fallen leaves of trees and other plants, and gulp air at the surface of the water. It is said that they sometimes leave the water, but as their fins are weak it is not likely that they travel far. The Barramunda (*C. forsteri*) attains a length of six feet, and has salmon-coloured flesh which is valued as food. Of the development of this type nothing is as yet known, but the eggs are like those of the newt in size, and are laid in strings surrounded by a jelly. Gerhard Krefft described *C. forsteri* in 1870, and about the same time Günther investigated the structure of *C. miolepis*, and recognised the importance of the type.

Protopterus annectens lives in fresh water in tropical Africa, especially to the west. It feeds on fish, frogs, insects, and other small animals. The limbs are linear, and are moved like the legs of a newt. Besides the paired lungs and the internal gills, there are three external gill-like outgrowths, like those of young tadpoles. When the ponds dry up, the fish buries itself in the mud, and remains there till the rains refill the pools. Hardened "mud-nests" have been dug out and brought to Europe without injury to the enclosed *Protopterus*.

Of *Lepidosiren paradoxa*, discovered about fifty years ago by Natterer in the rivers of Brazil, little is known, but it seems to be only a species of *Protopterus*.

The limb of *Ceratodus* is trowel-shaped, and consists of a central axis with bilateral rays; that of *Protopterus* is linear, the central axis bearing but a slight lateral membrane without rays.

In *Ceratodus* the lung is single; in *Protopterus* it is double. The tube to the lung springs from the ventral side of the gullet.

In *Ceratodus* there are four gills on each side; in *Protopterus* there are two and a half. Moreover, in *Protopterus* there are the external gills already mentioned.

As a pulmonary circulation has been established, the heart is more complex than in other fishes. It is like the heart of Amphibians. The sinus venosus is divided into two sections—a right systemic, a left pulmonary; the cavity of the auricle is also divided. The spirally twisted conus arteriosus is divided into two channels by a complete septum in *Protopterus*; in *Ceratodus* there is a complex system of valves, but the division into two paths is incomplete.

From the ventral aorta, alike in *Ceratodus* and *Protopterus*, four pairs of branchial arteries arise. In *Ceratodus*, the two anterior pairs carry mixed blood; in *Protopterus*, they carry pure blood—a difference due to the imperfection of the partition in the conus of *Ceratodus*. Only in *Ceratodus*, moreover, are there internal gills corresponding to the first two pairs of branchial arteries, though the first external gill of *Protopterus* is supplied from the second branchial artery, as are the following two from the third and fourth. The efferent branchial arteries form a dorsal aorta as usual, but from the fourth efferent branchial arises the pulmonary artery. Thus the blood which returns from the lung to the left auricle has been twice purified.

That the Dipnoi are ancient may be inferred from their structure and distribution. *Ceradotus* was represented in the Permian (?) and Triassic, and related extinct forms appeared much earlier, such as *Dipterus* in the Devonian, *Ctenodus* from Carboniferous to Permian.

The affinities of Dipnoi and Amphibians are very close, especially as regards the respiratory and the circulatory systems. Indeed, Dipnoi have been called "perennially aquatic Amphibians."

Order III. Ganoidei.

This ancient order of armoured fishes flourished in Devonian and Carboniferous ages, but is now represented by only seven genera, of which the Sturgeon (*Acipenser*) and the Bony Pike (*Lepidosteus*) are the most familiar.

General Characters.—The skin bears large scales, or bony scutes. The tail is either heterocercal or homocercal. Membrane bones invest the skull and shoulder girdle. The endoskeleton is in great part cartilaginous in *Acipenser*, *Scaphirhynchus*, and *Spatularia*, but is ossified in *Lepidosteus*, *Polypterus*, *Calamoichthys*, and *Amia*. In the first three, the notochord is unconstricted; in the others there are distinct vertebral bodies, opisthocœlous in *Lepidosteus*, amphicœlous in the other three genera. The fore-brain has a non-nervous roof. There is a spiral valve in the intestine, but it is very small in *Lepidosteus*. The food-canal ends apart from and in front of the urinogenital aperture. There are also abdominal pores. An air-bladder is present with a persistent open duct. The openings of the gill-clefts are covered by an operculum supported by bones; in some of the genera there is a spiracle. A conus arteriosus is associated with the ventricle. The archinephric or segmental ducts do not divide; thus no Müllerian ducts are formed; the pronephros completely degenerates. The ova are small, and are fertilised

in the water; they have comparatively little yolk, and so far as we know, their segmentation is holoblastic.

Genera.—The sturgeon (*Acipenser*) is one of the more cartilaginous Ganoids. The skin bears five rows of large bony scutes; the tail is asymmetrical or heterocercal; the notochord is unsegmented. A snout, bearing pendent barbules, extends in front of the ventral mouth which is rounded and toothless. Sturgeons feed on other fishes which they swallow whole. They are the largest fishes found in fresh water, for *A. sturio* may attain a length of 18 feet, and a weight of 600 pounds, while the *A. huso* of Southern Russia may measure 25 feet, and weigh nearly 3000 pounds! Most of the species are found both in the sea and in rivers or lakes. The flesh is edible, except in the case of the green sturgeon, *A. medirostris* of the Pacific coasts, which is said to be poisonous; the roes or ovaries form caviare; the gelatinous internal layer of the swim-bladder is used as isinglass. The genus *Scaphirhynchus* is represented in Asia and the United States; *Polyodon* or *Spatularia spatula* is the paddle-fish or spoon-bill of the Mississippi. In *Polypterus*, from the Nile and other African rivers, the dorsal fin is divided into many parts, the nasal-sac has a complex labyrinthine structure, the swim-bladder arises from the ventral side of the gullet, the young are said to have external gills. In Old Calabar there is a related genus *Calamoichthys*. The gar-pike or bony-pike—*Lepidosteus*—is covered with rows of enamelled scales; the whole skeleton is well ossified, and the vertebral bodies are opisthocœlous or concave behind; the swim-bladder is like a lung in structure, and to some extent in function. The bow-fin, *Amia calva*, frequenting still waters in the United States, has a similar lung-like swim-bladder.

The fossil Ganoids appear in the Silurian about the same time as the Elasmobranchs, they are abundant from the Devonian to the Upper Cretaceous when the Teleosteans begin to become numerous. According to Traquair, a Proganoid series of primitive forms, such as *Pteraspis*, *Cephalaspis*, *Pterichthys*, *Coccosteus*, should be distinguished from the Euganoid series of typical forms, such as *Holoptychius*, *Rhizodus*, *Osteolepis*, *Chondrosteus*.

Order IV. TELEOSTEI—the "Bony Fishes."

This order includes most of the fishes now alive. As they do not appear before the Cretaceous period, the Teleosteans are relatively modern fishes. They are the successors and perhaps the descendants of the Ganoids.

General Characters.—The skeleton is well ossified, with numerous investing bones on the skull, others in the operculum, and on the shoulder girdle. The tail is sometimes quite symmetrical or diphycercal, but in most cases it is heterocercal at first, and acquires a secondary symmetry termed homocercal, for while the end of the notochord in

the young forms is bent upwards as usual, the subsequent development of rays produces an apparent symmetry. The scales are in most cases relatively soft. As in Ganoids, the roof of the fore-brain is without nervous matter. The optic nerves are remarkable because they cross one another without fusing; in other words they are decussate. As in Ganoids, the partitions between the gill-clefts disappear, so instead of the pouches seen in Elasmobranchs, there is, on each side, one branchial chamber, covered over by an opercular fold. Into this chamber the gill-filaments borne by the branchial arches project freely. In most, a swim-bladder is developed from the dorsal side of the gullet. There is no spiral valve in the intestine, and the food-canal ends in front of and separate from the genital and urinary apertures or aperture. The base of the ventral aorta is swollen into a non-contractile bulbus arteriosus, but there is no conus, unless very exceptionally, as in *Butirinus*. According to some authorities, the archinephric duct is unsplit, and there is no Müllerian duct; according to Jungersen, the oviduct is a true Müllerian duct. The pronephros degenerates; the ova are numerous, and are fertilised in the water.

Classification of Teleostei. (After Günther.)

Before mentioning the principal sub-orders of Teleostei, it is convenient to distinguish two sets of aberrant forms :—

(*a*) The sea-horses, such as *Hippocampus* and *Phyllopteryx*, and the pipe-fishes, such as *Syngnathus*, are distinguished as Lophobranchii. The gills, instead of being rows of filaments, are tufts of rounded lobes; the gill-cover is a simple plate leaving a small aperture; the skin is more or less protected by large dermal plates; the toothless mouth is at the end of a prolonged snout.

(*b*) The globe-fishes, such as *Tetrodon* and *Diodon*, the trunk-fishes —*Ostracion*, the sun-fish—*Orthagoriscus* and others, are distinguished as Plectognathi. The body is globular or compressed sideways; the skin bears bony scutes or spines or is naked; the skeleton is incompletely ossified, and the vertebræ are few; the bones of the upper jaw are more or less fused; the pelvic fins are absent or reduced to spines; the gills are comb-like; the swim-bladder has no duct.

It is likely that some of the loosely-built deep-sea fishes, such as the pelican fish *Eurypharynx* are not referable to the orders usually recognised. But the great majority of living fishes may be classified as follows :—

Dorsal, anal, and pelvic fins in part spiny.	Acanthopteri. Example—Perch.	Physoclisti, — duct of swim-bladder is closed.
	Pharyngognathi. Example — Wrass.	
The dorsal, anal, and pelvic fins without spines.	Anacanthini; the pelvic fins are situated far forward. Examples —Cod, Flounder.	
	Physostomi; duct of swim-bladder remains open. Examples—Herring, Salmon, Carp, Eel.	

The Haddock (*Gadus æglefinus*)—A type of Teleosteans with closed swim-bladder (Physoclisti).

Form and External Features.—The elongated wedge-like form is well adapted for rapid swimming. The terminal mouth bears a short barbule; this is long in the cod *(G. morrhua)* and absent in the whiting *(G. merlangus).* The nostrils, situated near the end of the snout, have double apertures. The eyes are lidless, but covered with transparent skin. Over the gill-chamber and the four gills lies the operculum, supported by several bones. Distinct from one another, but closely adjacent, are the anal, genital, and urinary apertures,—named in order from before backwards. Along the sides of the body runs the black lateral line containing sensory cells. There are three dorsal and two anal fins, and an apparently symmetrical tail-fin.

Skin.—The small scales which cover the body are developed in the dermis, and are without any bone-cells. Their free margin is even, a characteristic to which the term cycloid is applied, in contrast to ctenoid, which describes those scales which have a notched or comb-like free margin. Over the scales extends a delicate partially pigmented epidermis.

Appendages.—The pectoral fins are attached to the shoulder girdle just behind the branchial aperture. The pelvic or ventral fins, attached to what is at most a rudiment of the pelvic girdle, lie below and slightly in front of the pectorals—far from the normal position of hind limbs.

Muscular System.—The main muscles of the body are disposed in segments,—myotomes or myomeres, separated by partitions of connective tissue.

Skeleton.—The Vertebral column consists of biconcave or amphicœlous bony vertebræ. Each centrum in the trunk

region bears superior neural processes, uniting in a neural arch crowned by a neural spine, and transverse processes projecting from each side. Articulated to the distal ends of the transverse processes are the downward curving ribs, and also more delicate inter-muscular bones which curve upwards. In the caudal vertebræ, the centra bear not only superior neural processes, but also inferior hæmal processes.

At the end of the vertebral column lies a fan-shaped hypural bone which helps to support the tail. The fin-rays are jointed flexible rods, which in dorsal and anal fins are attached to the ends of interspinous bones alternating with the neural and hæmal spines, and attached to them by fibrous tissue.

The Skull includes the following bones, whose relative positions are roughly indicated by that of their names. Those of the membrane bones are printed in italics :—

	Mesethmoid.		*Frontal.*		*Supra*-occipital.
Nasal.			*Parietal.*		
			Sphenotic.	Pterotic.	Epiotic.
	Parethmoid.		Alisphenoid.		
	Lachrymal.	*Orbitals.*	Prootic.	Opisthotic.	Ex-occipital.
Vomer.		*P-a-r-a-s-p-h-e-n-oid.*			Basi-occipital.

The first or mandibular arch is believed by many to form Meckel's cartilage beneath, and the palato-pterygo-quadrate cartilage above. Meckel's cartilage becomes the foundation of the lower jaw, and bears a large tooth-bearing membrane bone—the dentary, a small corner bone—the angular, while the articular element is a cartilage bone. Of the bones associated with the upper part, the palatine lies in front, the quadrate articulates with the lower jaw; while between palatine and quadrate lie the pterygoid, the mesopterygoid, and the metapterygoid.

The second or hyoid arch is believed by many to form the hyomandibular and the symplectic above, and various hyoid bones beneath. The hyomandibular and its inferior segment the symplectic connect the quadrate with the side of the skull. Of the six hyal bones, the largest and most important is the ceratohyal, which bears seven long branchiostegal rays.

The toothed premaxilla forms the upper part of the gape,

while the maxilla which articulates dorsally with the vomer, and nearly reaches the quadrate posteriorly, does not enter into the gape. Both are membrane bones.

In the opercular fold are four membrane bones.

The branchial arches are divided into various parts, of which the most interesting are the two superior pharyngeal bones which lie in the roof of the pharynx and bear teeth, and their counterpart, the inferior pharyngeal bone, which lies on the floor of the pharynx, and is likewise toothed.

The Limbs and Girdles.—The fin-rays of the pectoral fin are attached to four small brachial ossicles; these articulate with a dorsal scapula and a more ventral coracoid; both of these are attached to the inner face of a large clavicle, which curves to meet its fellow of the other side in the mid-ventral line of the throat. From the clavicle a slender post-clavicle extends backwards and downwards; while a stout supra-clavicle extends from the dorsal end of the clavicle upwards to articulate with a forked post-temporal, which articulates with the back of the skull. It must not be assumed that the elements of this girdle are directly comparable to those of a higher Vertebrate, although the nomenclature is the same.

The fin-rays of each pelvic fin are attached to a thin innominate bone, which may be a basal element of the fin, or the rudiment of a pelvic girdle.

Nervous System.—The relatively small cerebral hemispheres, the thalamencephalon with its inferior lobes and infundibulum, the large optic lobes, the tongue-shaped cerebellum which conceals most of the medulla oblongata, have their usual relations. Each of the olfactory nerves is at first double; their bulb-like terminations lie far from the brain behind the nasal sacs. The large optic nerves cross one another without fusion at a slight distance from their origin. But the relations of these and the rest may be inferred from our description of the skate.

In the large eyes, the different parts will be readily identified; the small nasal sacs with plaited walls have double anterior apertures; the vestibule of the ear contains a large otolith, and another very small one in a posterior chamber. The black lateral line, covered over by modified scales, lodges sensory tubes, and is innervated by a branch of the vagus.

Alimentary System.—Teeth are borne by the premaxillæ, the vomer, and the superior pharyngeal bones above, by the dentaries and the inferior pharyngeal bone beneath. There are no salivary glands, nor spiracles, nor posterior nares. A small tongue is supported by a ventral part of the hyoid arch. Five gill-clefts open from the pharynx; their inner margins are fringed by horny gill-rakers attached to the branchial arches and serving as strainers. The gullet leads into a curved stomach; at the junction of stomach and duodenum numerous tubular pyloric cæca are given off; into the duodenum opens the bile-duct from the gall-bladder and liver; the intestine passes gradually into the rectum, which has an aperture apart from those of the genital and urinary ducts. It will be noted that a pancreas is absent; perhaps the pyloric cæca take its place. Nor can one fail to remark the darkly pigmented peritoneal membrane which lines the abdominal cavity.

Respiratory System.—Water that passes in by the mouth may pass out by the gill-clefts; the branchial chamber is also washed by water which passes both in and out under the operculum. The gill-filaments borne on the four anterior branchial arches are long triangular processes, whose free ends form a double row. As there are no partitions between the five gill-clefts, the filaments project freely into the cavity covered by the operculum. Along each arch and filament there are blood-vessels, bringing the impure blood, and removing it purified. On the internal surface of the operculum lies a red patch, the pseudobranch or rudimentary hyoidean gill.

The swim-bladder lies along the dorsal wall of the abdomen; the duct which originally connected it with the gut has been closed. The dorsal wall of the bladder is so thin, that the kidneys and vertebræ are seen through it; the ventral wall is thick, and bears anteriorly a large vascular rete mirabile, which receives blood from the mesenteric artery and returns blood to the portal vein.

Circulatory System.—The heart lies within a pericardial chamber, separated by a firm partition from the abdominal cavity. The blood from the body and liver enters the heart by the sinus venosus, passes into the thin-walled auricle, and thence to the muscular ventricle. From the ventricle it is

DIAGRAM XXVII.

TELEOSTEANS.

The uppermost figure shews the familiar shape of the haddock. *Na.* nasal apertures ; *Pelv.* pelvic fin ; *Pect.* pectoral fin. The unpaired fins and the muscle segments are also shewn.

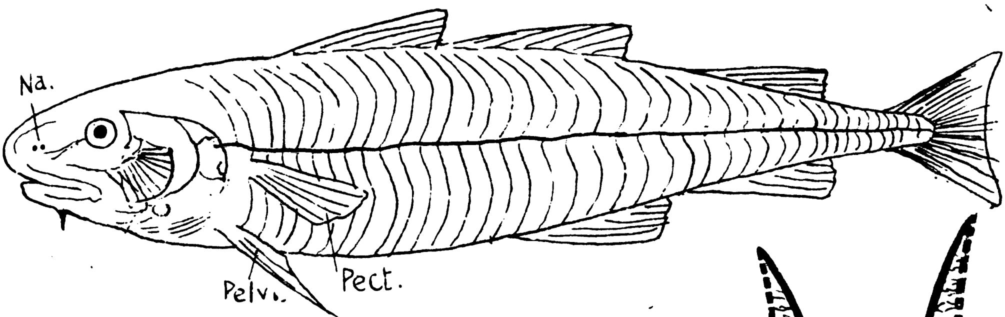
The figure named *Circ.* (after Nuhn), shews the heart with the sinus venosus (*s. v.*), the auricle (*A.*), the bulbus asteriosus (*B. a.*) in front of the ventricle ; the ventral aorta giving off afferent branchials (*a. b.*) ; the efferent branchials (*eff. b.*) ; the carotids (*ca.*) rising from the cephalic circle in front ; the aortic trunks (*a*) uniting in the dorsal aorta (*d. a.*) ; the cardinal venus (*card.*) bringing back impure blood to the heart.

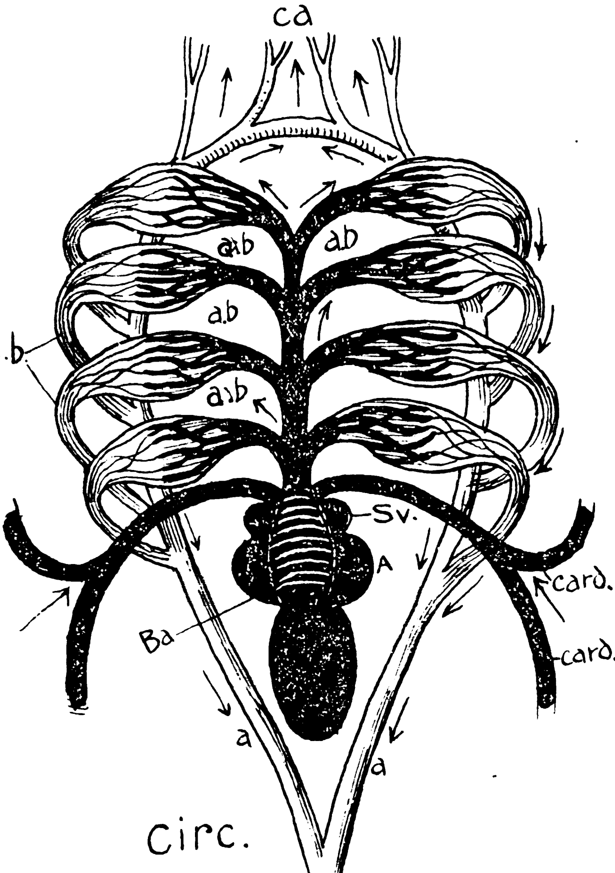
The *Gill-filament* (after Nuhn) shews the two currents of blood—the venous vessels (solid black), the arterial vessels (interrupted lines).

The figure *Limb* (from Gegenbaur) shews the pectoral fin ; *cl.* the clavicle ; *sc.* the scapula ; *cor.* the coracoid ; *b. p.* the basal pieces ; *r.* the fin-rays ; *p. cl.* the post-clavicle ; *s. cl.* the supra-clavicle ; *p. t.* the post-temporal.

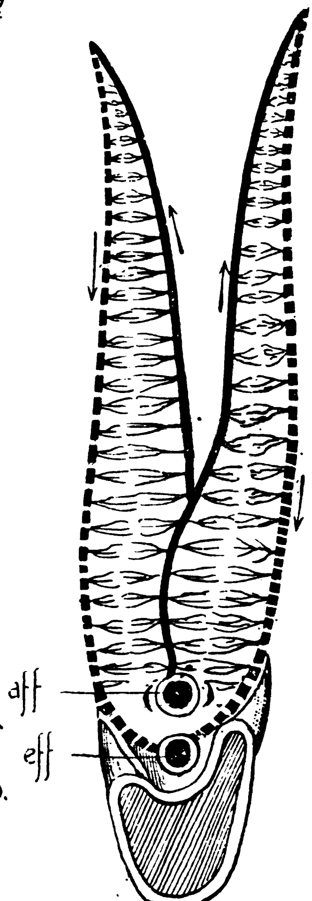
The *Ceratodus fin* (after Günther) is an archipterygium with a central axis bearing lateral fin-rays.

Teleosteans.

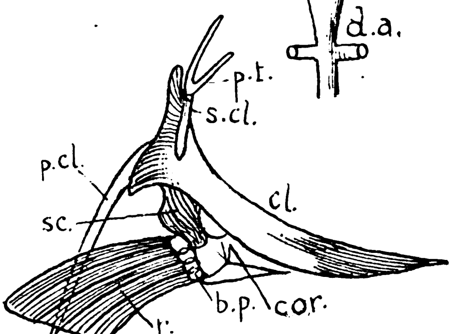




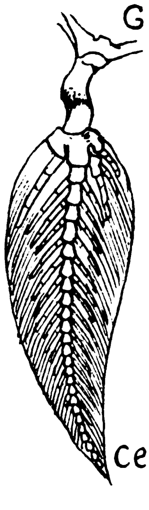
Circ.



Gill-filament.



Limb.



ceratodus fin.

driven up the ventral aorta, the base of which forms a white non-contractile bulbus arteriosus.

The ventral aorta gives off on each side four afferent branchial vessels to the gills. Thence the blood is collected by four efferent trunks, which unite on each side in an epibranchial artery. The two epibranchials are united posteriorly to form the dorsal aorta, while anteriorly they give off the carotids which are united by a transverse vessel closing the "cephalic circle."

Just before the epibranchials unite to form the dorsal aorta, each gives off a subclavian to the pectoral fin. The cœliac and the mesenteric arteries arise from the right epibranchial in front of the subclavian. From the ventral region of the first efferent trunk, a hyoidean artery arises; it gives off a branch to the pseudobranch, and another to join the epibranchials. Blood leaves the pseudobranch by an ophthalmic artery, which is connected with its fellow on the opposite side, but is continued forwards to the choroid of the eye. From the combined bases of the hyoidean, and the two first efferent branchials, an artery is given off on each side ventrally; the two unite in a median vessel which supplies pericardium, heart, and pelvic fins.

Blood enters the sinus venosus by two vertical precaval veins, and by hepatics from the liver. Each precaval vein is composed dorsally of a jugular from the head and a cardinal from the body. The cardinals extend along the kidneys and are continuous posteriorly with the caudal vein, but the middle part of the left cardinal is obliterated.

Excretory System.—The kidneys are very long bodies, extending above the swim-bladder under the vertebral column. The largest parts lie just in front of and just behind the swim-bladder. From the posterior part an unpaired ureter extends to the urinary aperture, before reaching which it gives off a small bilobed bladder. The pronephros degenerates; the functional kidney is a mesonephros.

Reproductive System.—The testes are long lobed organs, conspicuous in mature males at the breeding season. The ovaries of the female are more compact sacs, more restrictedly posterior in position.

Two vasa deferentia combine in a single canal. The likewise single oviduct is continuous with the cavity of the ovaries. The genital aperture in either sex is in front of, but very close to, that of the ureter. According to some

authorities the genital canals in Teleosteans are secondary structures, unconnected with the archinephric or segmental ducts, but the researches of Jungersen have made this very doubtful.

Development.—The ova of the haddock, like those of other Teleosteans, contain a considerable quantity of yolk, are fertilised after they have been laid, and undergo meroblastic segmentation.

At one pole of a transparent sphere of yolk, lies a disc of formative protoplasm of a light terra-cotta colour. The ovum is surrounded by a firm vitelline membrane. After fertilisation, the formative disc divides first into two, then into four, then into many cells which form the blastoderm. From the edge of the blastoderm certain yolk-nuclei or periblast-nuclei are formed which afterwards have some importance. At the end of segmentation, the blastoderm lies in the form of a doubly convex lens in a shallow concavity of the yolk.

The blastoderm extends for some distance laterally over the yolk; the central part raises itself, and thus forms a closed segmentation cavity; one radius of the blastoderm becomes thicker than the rest, and forms the first hint of the embryo; an inward growth from the edge of the blastoderm forms an invaginated layer—the dorsal hypoblast or roof of the gut; the periblast forms the floor of the gut, and afterwards aids the mesoblast which appears between epiblast and hypoblast; the medullary canal is formed as usual in the dorsal epiblast. It is likely that the edge of blastoderm represents the blastopore or mouth of the gastrula, much disguised by the presence of yolk.

The newly hatched larva is still mouthless, and lives for a while on the residue of yolk, which by its buoyancy causes the young fish to be suspended in the water back downwards.

The Herring—*Clupea harengus*. A type of those Teleosteans which have the swim-bladder communicating with the gut (Physostomi).

In habit the herring is pelagic and gregarious. It is found in the North Sea, the temperate and colder parts of the Atlantic, the Baltic, and the White Sea. A similar species lives in the N. Pacific.

External Characters.—The herring has the typical "fish" shape. Externally it differs from the haddock in the following features:—there is no barbule; the maxilla is divided into three parts; the nostrils have a single aperture on each side; there is no lateral line; the pelvic fins are abdominal, not jugular in position; there is one dorsal and one anal

fin; the body is more compressed; the ventral edge is covered by a "series of sharply keeled bony shields."

Nervous System.—The brain has very small cerebral hemispheres and large optic lobes. The ear has a peculiar connection with the swim-bladder. External to each of the well-developed eyes are two immovable transparent folds of skin, with a vertical slit between.

Alimentary System.—The mouth has a narrowed gape. The upper jaw moves downwards and forwards when the mouth is opened. Small visible teeth are borne on the tongue and on the vomer, but those on both jaws are inconspicuous. The food—chiefly small crustaceans—is probably in part crushed by the gill rakers, which also prevent it passing out by the gill clefts. In the region of the gill arches a median opening leads into the gullet, which passes into a conical cæcum or crop. A narrow communication leads from beneath this crop to a thick-walled, gizzard-like, muscular organ directed forwards. This in turn has an opening into the intestine, which runs straight to the anus. About twenty digestive cæca open into the beginning of the intestine. The swim-bladder has a silvery exterior, and lies close under the back-bone. The herring differs from most Physostomi, as regards the connection between the swim-bladder and gut, for the bladder does not communicate with the gullet but with the crop by means of a narrow, twisted canal. Anteriorly on each side the swim- or air-bladder gives off a thin duct which, passing through the walls of the skull, divides into two branches, each ending in a dilatation close to the ear. Posteriorly the swim-bladder has a duct opening externally on the left side of the anus.

Respiratory System.—The gill filaments are fixed in a double row on the outer edge of each branchial arch. The specially wide opening behind the gill cover permits of a free current of water for respiration.

Reproductive System.—The testes or milt of the male and the ovaries or roe of the female, lie on each side of the abdominal cavity. In each sex there is a single external opening behind the anus. The number of mature eggs spawned at one time by the female has been variously estimated at from 10,000 to 30,000. In British waters there is a spring as well as an autumn spawning—probably however

SOME CONTRASTS BETWEEN THE FOUR ORDERS OF FISHES.

	Elasmobranchii.	Dipnoi.	Ganoidei.	Teleostei.
Scales.	Often with tooth-like placoid scales.	With soft large scales.	Usually with Ganoid bony scutes.	Usually with soft cycloid or ctenoid scales.
Limbs.	Large pectoral fins; claspers associated with the pelvic fins of the males.	A median axis in the fin—an "archipterygium."	No marked peculiarity.	Pelvic fins often far forward.
Tail.	Asymmetrical or heterocercal tail.	Primitively symmetrical, diphycercal or protocercal tail.	The tail is heterocercal or homocercal.	The tail is sometimes diphycercal, but usually asymmetrical, acquiring a secondary symmetry described as homocercal.
Skeleton.	Cartilaginous, except in a few parts, such as scales and teeth. In a few the notochord is unconstricted, in most it persists only between the vertebræ.	In part cartilaginous, in part ossified: the notochord is unconstricted.	Mainly cartilaginous in some, ossified in others, always with numerous membrane bones. In the cartilaginous Ganoids, the notochord is unconstricted: in the others it persists only between the vertebræ.	Well ossified. The notochord persists only between the biconcave vertebræ.
Nervous System.	The roof of the fore-brain is composed of nervous material.	As in Elasmobranchs.	The roof of the fore-brain consists of non-nervous material.	As in Ganoids. The optic nerves decussate, or cross without fusing.

Gut.	Transverse ventral mouth; a spiral valve; a cloaca; abdominal pores.	A spiral valve; a cloaca; abdominal pores. Posterior nares open into the mouth.	A spiral valve; a distinct anus; abdominal pores.	No spiral valve; a distinct anus.
Respiratory System.	No operculum; persistent partitions between gills; there is usually a spiracle; there is no air-bladder.	An operculum; a single branchial chamber; no spiracle; the air-bladder forms a single or double "lung."	An operculum; a single branchial chamber; a spiracle in some; the air-bladder with an open duct is sometimes lung-like.	An operculum; a single branchial chamber; no spiracle; there is usually an air-bladder with an open or closed duct.
Heart.	Contractile conus arteriosus.	As in Elasmobranchs, but the auricle is divided by a partition, receiving pure as well as impure blood, and the heart is in some other respects peculiar.	As in Elasmobranchs.	A non-contractile bulbus arteriosus.
Urino-genital System.	Pronephros of some significance; the segmental duct splits into Müllerian (oviduct in female), and Wolffian (vas deferens in male).	As in Elasmobranchs.	Pronephros of no significance. The segmental duct does not split as it does in Elasmobranchs.	As in Ganoids, according to some authorities; but, according to Jungersen, the oviduct is a true Müllerian duct.
Ova.	Large, few, fertilised within the body, sometimes hatched there, usually laid in horny purses. Meroblastic segmentation. The embryos have transitory external gills.	Small, few, in all likelihood fertilised outside of the body, and with holoblastic segmentation, but the development is unknown.	Small, numerous, externally fertilised, and holoblastic so far as is known.	Small numerous, in almost all cases fertilised outside of the body; the segmentation is meroblastic.

by distinct shoals of herrings. When about to spawn, the herring come near the coasts into water of from ten to twenty fathoms depth. While the eggs are being shed by the females, the spermatic fluid is passed into the water by the males, and the eggs are thus fertilised before reaching the bottom, where they adhere to stones, zoophytes, and even crustaceans. The optimum temperature for spawning appears to be 55° F. The incubation of the eggs takes from 6–8 days at a temperature of 53° F. to 40 days at 38° F.

Development.—The young herring on emerging from the egg has the yolk-sac attached; its skeleton is rudimentary; it has no scales; the ventral fins are undeveloped; one continuous fin passes along the back, round the tail to the anus. A month after hatching, the larva is about two-thirds of an inch long, and has absorbed all its yolk. About the third month the scales appear, and though only two inches in length, the form is then that of the adult. Growth continues at the rate of less than half an inch per month, and at the end of eighteen months the herring is sexually mature.

Closely allied to the herring are the sprat, the shad and the pilchard. Thames "whitebait" are herring not six months old.

The relationships of Fishes.

Balfour regarded the Elasmobranchs as nearest the ancestral stock; while from hypothetical Proto-Ganoids he derived on the one hand the Dipnoi, on the other hand the Ganoids, and thence the Teleosteans.

But it must be noted that the Dipnoi are markedly separated in many ways from living Ganoids. To emphasise this I have placed them next Elasmobranchs. Moreover, the extinct Ganoids form a very large and diverse series, which cannot be fairly appreciated by a study of the few survivors.

Günther distinguishes the sub-class Teleostei from the sub-class Palæichthyes, including under the latter the Chondropterygii (Elasmobranchs and Holocephala) and the Ganoidei (along with which Dipnoi are ranked). As two other sub-classes of Fishes, he recognises the Cyclostomata and the Leptocardii (*Amphioxus*).

Beard proposes the following classification of Ichthyopsida, insisting especially on the separateness of Dipnoi from Ganoids, and on their nearness to Amphibians:—

$$\text{Ganodichthyidæ.}\ \left\{\begin{array}{l}\text{Marsipobranchii (Cyclostomata).}\\ \text{Ganoidei.}\\ \text{Teleostei.}\end{array}\right.$$

$$\text{Selachodichthyidæ.}\ \left\{\begin{array}{l}\text{Selachii.}\\ \text{Pneumichthyidæ.}\ \left\{\begin{array}{l}\text{Dipnoi.}\\ \text{Amphibia.}\end{array}\right.\end{array}\right.$$

CHAPTER XXII.

AMPHIBIA.

AMONG living Amphibians there are three distinct orders :—the frogs and toads in which the tail is absorbed before adult life is attained, the newts and salamanders in which the tail persists, and the worm-like limb-less Cæcilians. The first two orders have some extinct representatives, but most of the Amphibian fossils belong to a distinct set, and are usually united in the order Labyrinthodontia. Thus the class includes at least four orders :—

Labyrinthodontia or Stegocephala, wholly extinct, such as *Mastodonsaurus* and *Dendrerpetum*.

Gymnophiona or Apoda, tailless worm-like forms, subterranean in habit, such as *Cæcilia* ;

Urodela or Caudata, with persistent tails, such as newts and salamanders ;

Anura or Ecaudata, tailless in adult life, such as frog and toad ;

General Characters.—The Amphibians are almost without exception aquatic in their youth, but the adults become more or less terrestrial. The young forms always breathe by gills, and in some cases this mode of respiration is retained throughout life. All, however, acquire functional lungs. The heart is three-chambered, having two auricles and a ventricle.

The limbs have distinct digits; unpaired fins which are almost always present in the larvæ, and sometimes in the adults as well, have no fin-rays ; the skin is soft and glandular without any hint of exoskeleton except in a few exceptional cases.

The gut ends in a cloacal chamber into which the urinogenital ducts open, and from the hind end of the gut there

grows out an allantoic bladder, homologous with the allantois in the embryos of higher Vertebrates.

The ova are small, numerous, usually pigmented, and with yolk towards one pole. They are almost always laid in the water; the segmentation is holoblastic, but unequal. There is usually a metamorphosis in development. It is very difficult to distinguish Amphibians from Fishes, especially if we include the Dipnoi in the former class. The most obvious differences are the absence of fin-rays and the development of fingers and toes.

From the higher Vertebrates or Amniota, the Amphibians are clearly distinguished by the presence of gills in youth at least, and by the absence of an amnion and allantois. For though the bladder of Amphibians be homologous with an allantoic outgrowth, it does not function as such, in other words, it does not aid in the respiration or nutrition of the embryo.

ICHTHYOPSIDA.

Some of the common characters—

- Gills are always present, during youth at least.
- There is no amnion, and at most a homologue of the allantois.
- There are lateral sensory structures, such as "the branchial sense-organs" and those of the "lateral line," but they may be diminished in the adults.
- Unpaired fins are almost always represented, during youth at least.

FISHES.	AMPHIBIANS.
Gills persist throughout life.	Gills may disappear as the adult form is attained.
The swim-bladder functions as a lung in Dipnoi and less markedly in some Ganoids, but in most cases its respiratory significance is slight.	Lungs are always developed in the adults. It is doubtful whether they are directly comparable with the swim-bladder.
Except in Dipnoi, the heart has two chambers. There is no inferior vena cava.	The heart has three chambers. There is an inferior vena cava.
The limbs are fins.	The limbs have digits and correspond to those of Amniota.
The unpaired fins are supported by fin-rays.	There are no fin-rays.
The skull has one occipital condyle.	There are two occipital condyles.
There is usually an exoskeleton of scales or scutes.	There is no hint of exoskeleton, except in a few exceptional cases.
Except in Dipnoi, the nasal sacs do not open posteriorly into the mouth.	There are posterior nares opening into the cavity of the mouth.
There is no certain homologue of the allantois.	The bladder is the homologue of the allantois.

Life of Amphibians.—Most Amphibians live in or near fresh water ponds, swamps, and marshes. Even those adults which have lost all trace of gills, are usually fond of water. The tree-toads, such as *Hyla*, are usually arboreal in habit, while the Gymnophiona and some toads are subterranean.

The black Salamander (*Salamandra atra*) of the Alps lives where pools of water are scarce, and instead of bringing forth gilled young, as its relative the spotted salamander (*S. maculosa*) does, bears them as lung-breathers, and only a pair at a time. But if the unborn young are removed from the body of the mother and placed in water, they form gills like other tadpoles. Within the mother, the respiration and nutrition of the young seem to be effected by crowds of red blood-corpuscles which are discharged from the walls of the uterus.

Species of *Hylodes*, such as *H. martinicensis* of the West Indian Islands, live in regions where there are few pools. The development is completed within the egg-case, and a lung-breathing tailed larva is hatched in about fourteen days. It is likely that the tail helps in respiration before hatching, but one observer reported the presence of small gills.

In some Mexican and N. American lakes, there is an interesting amphibian known as *Amblystoma* or *Siredon*. It has two forms, one losing its gills (*Amblystoma*), the other retaining them (Axolotl). Both these forms reproduce, and both may occur in the same lake. Formerly they were referred to different genera. But the fact that some Axolotls, kept in the Jardin des Plantes in Paris, lost their gills when their surroundings were allowed to become less moist than usual, led naturalists to recognise that the two forms were but different phases of one species. It has been shown repeatedly, that a gilled Axolotl may be transformed into a form without gills, and this metamorphosis seems to occur constantly in one of the Rocky Mountain lakes. We must not leap to the conclusion, that a difference in the moistness of the environment alone determines whether this amphibian remain a gilled Axolotl or become a gill-less *Amblystoma*. For both forms may occur in the same lake, the change from Axolotl to *Amblystoma* may take place in the water, and besides the persistence or non-persistence of gills, there are other differenees between the two forms.

Amphibians are very defenceless, but their colours often conceal them. Not a few have considerable power of colour-change.

Many Amphibians live alone, but they usually congregate at the breeding seasons when the amorous males often croak noisily. Alike in their love and their hunger they are most active in the twilight.

Their food usually consists of worms, insects, slugs, and other small animals, but some of the larval forms are for a time vegetarian in diet. They are able to survive prolonged fasting, and many hibernate in the mud. Though the familiar tales of "toads within stones" are for the most part inaccurate, there is no doubt that both frogs and toads can survive prolonged imprisonment. Besides having great vital tenacity, Amphibians have considerable power of repairing injuries to the tail or limbs.

Although the life of Amphibians seems to have on an average a low potential, even the most sluggish wake up in connection with reproduc-

tion. The males often differ from their mates in size and colour. Some of their parental habits seem like strange experiments.

Thus in the Surinam toad (*Pipa americana*), the large eggs are placed by the male on the back of the female and fertilised there. The skin becomes much changed—doubtless in response to the strange irritation —and each fertilised ovum sinks into a little pocket, which is closed by a gelatinous lid. In these pockets the embryos develop, perhaps absorbing some nutritive material from the skin. They are hatched as miniature adults. In *Nototrema* and *Opisthodelphis*, the female has a dorsal pouch of skin opening posteriorly, and within this tadpoles are hatched. In *Rhinoderma darwinii*, the male carries the ova in his capacious croaking-sacs. In the case of the obstetric toad (*Alytes obstetricans*), not uncommon in some parts of the Continent, the male carries the strings of ova on his back and about his hind-legs, buries himself in damp earth until the development of the embryos is approaching completion, then plunges into a pool, where he is freed from his living burden. Thus among Amphibians, as among Fishes, the males sometimes take upon themselves the responsibility of hatching the eggs.

In the Anura the ova are fertilised by the male as they leave the oviduct; in the newt the male deposits a spermatophore in the water close to the female; in *Salamandra atra*, *S. maculosa*, and *Cæcilia compressicauda* the fertilisation must take place internally, for the young are hatched within the mother.

The eggs of the frog are laid in masses, each being surrounded by a globe of jelly; those of the toad are laid in long strings; those of newts are fixed singly to water plants; those of some tree-toads, such as *Hylodes*, are laid on or under leaves in moist places.

In *Salamandra atra*, *Pipa americana*, *Hylodes*, and *Cæcilia compressicauda*, the young are hatched as miniature adults; in the others there is more or less metamorphosis after birth.

There are about 900 living species of Amphibia, most of them tailless. All are averse to salt-water, hence their absence from almost all oceanic islands. The Anura are well-nigh cosmopolitan; the Urodela are limited to the temperate parts of the northern hemisphere.

The Frog (*Rana*) as a type of Amphibians.

The common British frog (*Rana temporaria*) and the Continental species (*R. esculenta*) often imported agree in all essential features. A black patch on the side of the head distinguishes *R. temporaria*; the males of *R. esculenta* have croaking sacs, and many other unimportant differences are noticeable.

Though aquatic in youth, frogs often live in dry places, hiding in great drought, reappearing when rain returns. Every one knows how they sit with humped back, how they

leap, how they swim. They feed on insects and slugs. These are caught by the large viscid tongue, which being fixed in front of the mouth and free behind, can be jerked out to some distance, and with even greater rapidity retracted. When we watch a frog carefully, we notice that the nostrils are alternately opened and closed, and that the under side of the throat is rhythmically expanded and compressed, the mouth remaining shut meanwhile; the movements are evidently concerned with respiration. That the males trumpet in the early spring to their weakly responsive mates, that in our British species the pairing takes place soon after, that the young are tadpoles, that a notable metamorphosis takes place, are familiar facts of observation. In winter the frogs hibernate, buried in the mud of the pond.

Form and External Features.—We notice the absence of neck and tail, the shorter fore-limbs almost without thumbs, the longer hind-limbs with five webbed nail-less toes and with a long ankle-region, the apparent hump-back where the hip-girdle is linked to the vertebral column. There is a very rudimentary thumb, and there is a horny knob at the base of the hallux or "great toe." At pairing time, the skin of the innermost digit of the fore-limb becomes modified in the males into a rough cushion, which is darkly coloured in *R. temporaria*.

We see the wide mouth, the paired nostrils, the projecting eyes with well-developed lids, the circular drum of the ear, the smooth yellowish skin with patches of other colours, and the cloacal aperture.

Skin.—The smooth, moist skin covers some parts of the body loosely; it consists of an external two-layered (ectodermic) epidermis, and an internal (mesodermic) dermis. The outer layer of the epidermis is shed periodically. The dermis differs markedly from that of a fish, for there is no exoskeleton; there are multicellular glands, whose secretion makes the skin moist; and there is also a stratum of unstriped muscle-fibres. In the dermis there are also branched pigment-cells, usually in two strata. Through a reflex nervous action they are slightly affected by the colour of the surroundings. Furthermore, there are cutaneous blood-vessels, by means of which the frog can to a certain extent breathe

by its skin. The tadpole has sensory cells arranged in distinct lateral lines, but of these the adult retains no definite trace, though there are many nerve-endings and "touch-spots" in the skin.

Skeleton.—The vertebral column consists of nine vertebræ, and an unsegmented portion called the urostyle.

The first vertebra bears two condylar facets for the two condyles of the skull and an odontoid process which lies between the condyles. Its arch is incompletely ossified. Each of the next six has an anteriorly concave or procœlous centrum, a neural arch surrounding the spinal cord, a transverse process from each side of the base of the arch, and an anterior and a posterior pair of articular processes. The eighth vertebra has a biconcave or amphicœlous centrum. The ninth is convex in front, with two convex tubercles behind, and bears large transverse processes with which the hip-girdle articulates. The urostyle has anteriorly a dorsal arch enclosing a prolongation of the spinal cord, but both arch and nerve cord disappear posteriorly. Remnants of the notochord, around which the vertebral column was constructed, persist only in the centres of the vertebræ.

The skull consists (*a*) of the persistent parts of the original cartilaginous brain-box or chondrocranium; (*b*) of ossifications within parts of the chondrocranium; (*c*) of membrane or investing bones, and (*d*) of associated visceral arches.

Part of the chondrocranium persists as an encasement of the brain. Two exoccipitals bounding the foramen magnum and forming the condyles, two pro-otics or ossifications of the original auditory capsule, and an unpaired sphenethmoid forming the front of the brain-case are cartilage-bones. Two parieto-frontals and two nasals above, a paired vomer and an unpaired dagger-shaped parasphenoid beneath, and two lateral hammer-shaped squamosals are membrane-bones.

To these are added the small pre-maxillæ in the very front of the skull, the long maxillæ on each side, the quadrato-jugals which continue the latter to the minute nodule which represents the quadrate bone.

On the roof of the mouth, extending from the quadrate forwards to near the vomers, are the triradiate pterygoids, while at right angles to the anterior end of the parasphenoid and behind the vomers are the palatines.

Each half of the lower jaw, based on Meckel's cartilage, consists of three pieces,—the largest an articular angulo-

DIAGRAM XXVIII.

THE FROG.

Skull 1 and *Skull* 2 (after W. K. Parker), show the under and upper aspects of the frog's skull:—*e.o.* ex-occipital; *p.o.* prootic; *par.* para-sphenoid; *sp.e.* sphenethmoid; *v.* vomer; *pm.* premaxilla; *mx.* max-illa; *pal.* palatine; *pt.* pterygoid; *q.j.* quadrato-jugal; *q.* quadrate; *sus.* suspensorium; *p.f.* parieto-frontal; *n.* nasal; *sq.* squamosal.

Corp. (after Auerbach) shows a much magnified red blood-corpuscle:—*Cm.* the cell-membrane; *C.* the cortical cell-substance; *M.* the me-dullary cell-substance; *N.* the nucleus; *Nu.* the nucleoli.

A, B, and C (from Balfour, after Ecker and Mivart), show three stages in the life-history of the frog. In A, the external gills and the suctorial pits (*s*) are shown.

Fig 1 (after Hertwig) shows the first segmentation of the ovum, *sp.* the nuclear spindle, *p.* the pigmented pole.

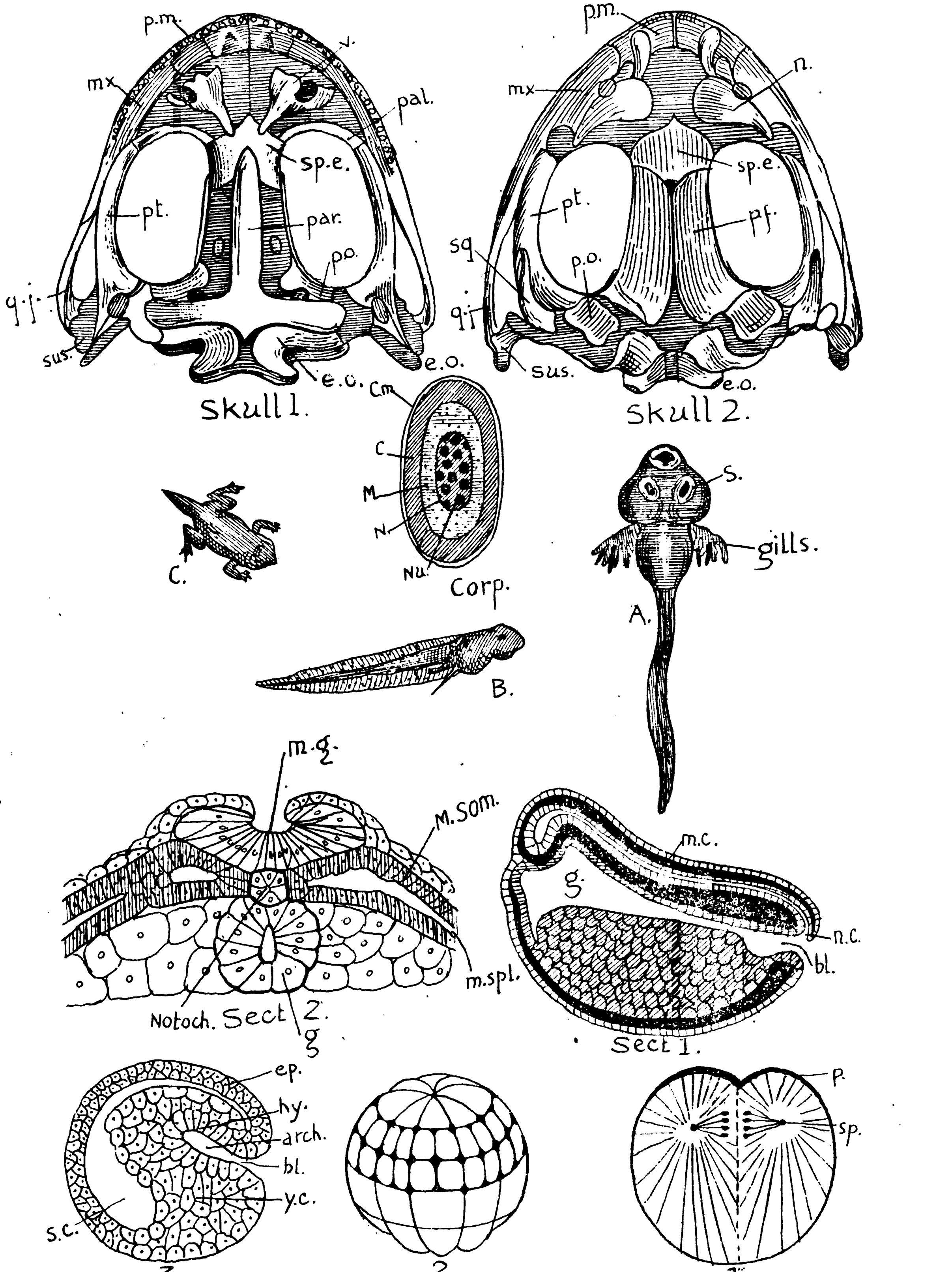
Fig 2 (after Ecker) shows segmented ovum with about 64 cells.

Fig 3 (after Hertwig) shows a section at the gastrula stage:—*ep.* the epiblast; *hy.* the invaginated hypoblast; *arch.* the archenteron; *bl.* the blastopore; *y.c.* the yolk cells; *s.c.* the segmentation cavity.

Sect. 1 (from Balfour, after Götte) shows a longitudinal section of an embryo frog:—*m.c.* the medullary canal; *n.c.* the neurenteric canal; *bl.* the blastopore; *g.* the primitive gut beneath which are the yolk-cells. The mesoblast is represented as solid black.

Sect. 2 (after Hertwig) is a transverse section:—*m.g.* the medullary groove; *notoch.* the notochord; *g.* the gut; *m. som.* the somatic meso-blast; *m.spl.* the splanchnic mesoblast.

Frog.


p.m.
v.
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Skull 1.
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Skull 2.
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splenial, outside this a thin dentary, and anteriorly uniting with its fellow a minute mento-meckelian.

A delicate rod—the columella auris—extends from the tympanum to the fenestra ovalis in the internal capsule of the ear. According to Parker, it represents the upper part of the hyoid arch, the lower portion of which forms a cartilaginous or partially ossified hyoid plate which lies in the floor of the mouth, and is produced into two anterior and two posterior cornua. According to Villy, however, the columella is morphologically connected with the ear-capsule.

Teeth are borne by the premaxillæ, maxillæ, and vomers.

The cartilage which bears the quadrate at its lower end, and runs between pterygoid and squamosal, connecting the articulation of the lower jaw with the side of the skull at the auditory capsule, is called the suspensorium. In Elasmobranchs, the hyomandibular is the suspensorium ; in Teleosteans, the name is applied to the hyomandibular and symplectic ; in Sauropsida, the quadrate occasionally gets the same confusing title.

When the lower jaw is connected with the skull wholly by elements of the hyoid arch, as in most Elasmobranchs and Ganoids and all Teleosteans, the term hyostylic is used. When the connection is due to a quadrate element only, as in Amphibia and Sauropsida, it is called autostylic. When there is both a hyoid and a quadrate element, as in *Lepidosteus* among Ganoids, or a hyoid and a palatoquadrate, as in *Cestracion* among Elasmobranchs and perhaps also in Holocephali, the term amphistylic is used. Finally, it may be noted here that in Mammals the lower jaw articulates with the squamosal.

Summary in regard to the Skull.

(*a*) The chondrocranium, developed from parachordals and trabeculæ at the anterior end of the notochord, and including the auditory and the less important olfactory capsules, persists in great part.

(*b*) The exoccipitals, the pro-otics, and the sphenethmoid, are cartilage-bones developed from the ossification of part of the chondrocranium.

(*c*) There are more numerous membrane-bones, namely :—

On the roof of the skull, parieto-frontal and nasals ;
On the floor of the skull, vomers and parasphenoid ;
On the sides of the skull, the squamosals ;
In association with the upper jaw, the premaxillæ, maxillæ, pterygoids, and palatines.
In association with the lower jaw, the dentaries and angulo-splenials. (The mento-meckelians seem to arise from two lower labial cartilages.)

The first or mandibular arch gives origin inferiorly to Meckel's cartilage, which forms the basis and persistent core of the lower jaw, and superiorly to the palato-pterygo-quadrate cartilage which is represented in the adult by the minute quadrate bone, by the suspensorial cartilage, and by other cartilages which are invested by the pterygoid and palatine bones.

The second or hyoid arch gives origin inferiorly to the hyoid plate, superiorly, according to Parker, to the columella.

Of four posterior branchial arches, there are in the adult persistent remnants.

The Limbs and Girdles.—The shoulder girdle consists of a dorsal portion—the scapula and the partially cartilaginous supra-scapula, and of a ventral portion—the coracoid, and the clavicle, and the cartilaginous precoracoid on which the clavicle lies. There is some uncertainty, however, in regard to the relations of the last two. The cavity or glenoid fossa with which the upper-arm articulates, lies at the junction of scapula and coracoid, and is bounded by them.

Between the median ends of the coracoids lies a cartilaginous sternum ensheathed in bone, and prolonged posteriorly into a notched cartilaginous xiphisternum. Anterior to the sternum is a bony portion called the omosternum, which is prolonged forwards into an episternum cartilage. This sternum does not arise like that of higher Vertebrates from the ventral ends of ribs. Indeed, there are no ribs in the frog, unless they be minute rudiments at the ends of the tranverse processes.

The skeleton of the fore-limb consists of an upper-arm or humerus; a fore-arm in which the inner radius and the outer ulna are fused; a wrist or carpus including two proximal and three distal elements, and a central piece wedged in between them; five metacarpal bones, of which the first—corresponding to the absent thumb—is very small; and four fingers, of which the two innermost have two joints or phalanges, while the two others have three.

The pelvic girdle has a long V-shape, the ends of which are cartilaginous and articulate with the expanded transverse processes of the ninth or sacral vertebra. Each limb of the V is an ilium; the united posterior part consists of a fused pair of ischia, and a ventral cartilaginous pubic portion. Ilia, ischium, and pubes, unite in bounding the deep socket or acetabulum with which the hind-leg articulates.

The skeleton of the hind-limb consists of a thigh bone or femur; a lower leg formed from the united tibia and fibula; an ankle region or tarsus including two long proximal elements—the astragalus or tibiale and the calcaneum or fibulare—and two imperfectly ossified distal elements; five metatarsal bones; five toes, the first or hallux with two phalanges, the second also with two, the third with three, the fourth with four, the fifth with three; and, finally, outside the hallux a "calcar" which looks like an extra toe and consists of three pieces.

Muscular System.—I shall not describe the myology of any of the Vertebrate types. By help of the guides to practical work which I have cited, the student will readily find out what he wishes to know.

The muscles are enswathed in connective-tissue. They consist of bundles of muscle fibres, while at their ends or at one of them they are usually continued into strong tendons, which are more or less directly attached to parts of the skeleton.

Nervous System.—The brain, covered with a darkly pigmented pia mater, has, as usual, the following parts:—

The elongated cerebral hemispheres, with "olfactory lobes" in front of them, with anterior and posterior commissures and a slight corpus callosum connecting them;

The thalamencephalon gives origin dorsally to a pineal outgrowth, which, passing through the skull, ends beneath the skin and between the eyes in a pineal body, while on the ventral side there will be seen the chiasma or interlaced crossing of the optic nerves, a tongue-shaped mass called the tuber cinereum, and the infundibulum to which the pituitary body is attached;

The optic lobes, a pair of oval bodies between and below which is the iter;

The cerebellum, a very narrow transverse band;

The medulla oblongata, on the roof of which the pia mater forms a very vascular "choroid plexus."

The cranial nerves are, as usual, on each side the following:—

(1) Olfactory, from the olfactory lobe to the nose;
(2) Optic, crossing and interlacing with its fellow in the optic chiasma beneath the thalamencephalon;
(3) Oculomotor, to four muscles of the eye;
(4) Pathetic, to the superior oblique muscle of the eye;
(5) Trigeminal, with orbito-nasal, maxillary, and mandibular divisions;
(6) Abducens, to the external rectus muscle of the eye;
(7) Facial, arising along with the auditory, with a ganglion uniting with the Gasserian ganglion of the trigeminal, with a palatine branch to the roof of the mouth, and a hyoid branch to the lower jaw;
(8) Auditory, to the ear;
(9) Glossopharyngeal, to the tongue and some of its muscles; with a ganglion which unites with that of the tenth;
(10) Vagus, with branches to stomach, lung, heart, etc.

The student should refer back to the description of the skate, and to the chapter on the structure of Vertebrates.

The spinal cord gives origin to ten pairs of spinal nerves, and is swollen at the origin of those which supply the limbs. Around the union of the anterior and posterior roots lie sacs with crystals of carbonate of lime.

The "sympathetic system" consists of about ten pairs of ganglia—(*a*) united by branches to the spinal nerves, (*b*) united to one another by longitudinal trunks which accompany the dorsal aorta and the aortic arches, and end anteriorly in the Gasserian ganglion, (*c*) giving off branches to the heart, the aorta, and the viscera in the pelvic region.

Sense-Organs.—The eyes project on the top of the head and on the roof of the mouth. There are two lids, the upper thick and very slightly movable, the lower transparent and movable. The transparent cornea in front, the

firm sclerotic surrounding the eye-ball, and the sheath of the optic nerve, are as usual continuous. The next layer includes the vascular and pigmented choroid and the brilliant iris. Internally is the sensitive retina, while vitreous humour fills the cavity behind the lens.

The internal ears have the usual parts and lie within the auditory capsules, which are in great part bounded by the pro-otics. Connecting the fenestra ovalis of the ear with the tympanic membrane, which is flush with the skin, there is a delicate bony rod—the columella. It lies in the Eustachian tube, which opens into the mouth at the corner of the gape.

The nostrils open into small nasal cavities, with folded walls of sensitive membrane; the posterior nares open into the front of the mouth.

There are taste papillæ on the tongue, and touch spots on the skin.

Alimentary System.—The frog feeds in great part on insects, which it catches dexterously with its tongue. This is fixed in front and loose behind. There are teeth on the pre-maxillæ, maxillæ, and vomers. Into the cavity of the mouth the nasal sacs open anteriorly, and the Eustachian tubes posteriorly. The males of *Rana esculenta* have a pair of sacs which open into the mouth cavity at the angle of the jaw, and are dilated during croaking. The tongue bears numerous taste papillæ. Behind the tongue on the floor of the mouth is the glottis, the opening of the short larynx which leads to the lungs. The larynx is supported by two arytenoid cartilages and also by a ring; with the arytenoids the vocal cords are closely associated. The lungs are so near the mouth that laryngeal, tracheal, and bronchial regions are hardly distinguishable. On the floor of the mouth lies the hyoid cartilage, which serves for the insertion of numerous sets of muscles.

In the tadpole the walls of the pharynx bear gill-clefts, of which no distinct traces remain in the adult. The lungs are outgrowths of the gullet or œsophagus. The latter leads into a tubular stomach. This is separated by a pyloric constriction from the duodenum, or first part of the small intestine. Then follow the coils of the small intestine, the wider large intestine and the cloaca.

The liver has a right and a left lobe, the latter again subdivided. The gall-bladder lies between the right and left lobes; bile flows into it from the liver by a number of hepatic ducts, which are continued onwards to the duodenum in a common bile-duct. The pancreas lies in the mesentery between stomach and duodenum, and its secretion enters the distal portion of the bile-duct. The bladder is a ventral outgrowth of the cloaca, has no connection with the ureters, and seems to be homologous with the allantois of Reptiles, Birds, and Mammals.

Vascular System.—The heart, enclosed in a pericardium, is three-chambered, consisting of a muscular conical ventricle, which drives the blood to the body and the lungs, of a thin-walled right auricle, receiving impure blood from the body, and of a thin-walled left auricle receiving purified blood from the lungs. From each of the auricles blood enters the ventricle. The two superior venæ cavæ which bring back blood from the anterior regions of the body, and the inferior vena cava which brings back blood from the posterior parts, unite on the dorsal surface of the heart in a thin-walled sinus venosus, which serves as a porch to the right auricle. From the ventricle the blood is driven up a truncus arteriosus, which soon divides into two branches, each of which divides into three aortic arches. Thus we may distinguish five regions in the heart,—the ventricle, the right auricle, the left auricle, the sinus venosus, and the truncus arteriosus. The sinus venosus is the hindmost, the truncus arteriosus the most anterior part. The two auricles are often included in the term atrium, the undivided part of the truncus arteriosus next the ventricle is called the pylangium, the more anterior part from which the arches arise is known as the synangium. The truncus arteriosus corresponds, in greater part at least, to the conus arteriosus of many fishes.

As the heart continues to live after the frog is really dead, its contractions can be readily observed. The sinus venosus contracts first, then the two auricles simultaneously, and finally the ventricle. Although the ventricle receives both impure and pure blood, the structural arrangements are such, as will afterwards be explained, that most of the impure blood is driven to the lungs, the

purest blood to the head, and somewhat mixed blood to the body.

The blood contains in its fluid plasma—(*a*) yellowish "red" corpuscles with a definite rind, a distinct nucleus, and the pigment hæmoglobin, (*b*) white corpuscles or leucocytes, like small amœbæ in form and movements, (*c*) very minute bodies, usually colourless and variable in shape. When the blood clots, the plasma becomes a colourless serum, traversed by coagulated fibrin filaments, the red corpuscles often arrange themselves in rows, and the white corpuscles are entangled in the coagulated shreds. When the web of a living frog is examined under the microscope, it will be seen that the flow of blood is most rapid in the arteries, more sluggish in the veins, most slugglish in the capillaries or fine branches which connect the arteries and the veins. The red corpuscles are swept along most rapidly, and are often deformed by pressure; the leucocytes tend to cling to the walls of the capillaries, and may indeed pass through them.

The arterial system. Each aortic branch is triple, and divides into the following on each side:—

I. The carotid arch, the most anterior, corresponding to the first efferent branchial of the tadpole, gives off:—
   - a lingual artery to the tongue,
   - a carotid artery, which bears near the origin of the lingual a spongy swelling (the "carotid gland"), and gives off an external carotid to the mouth and the orbit, and an internal carotid to the brain.

II. The systemic arch, the median one of the three, corresponding to the second efferent branchial in the tadpole, gives off:—
   - the laryngeal artery to the larynx,
   - the œsophageal to the œsophagus,
   - the occipito-vertebral to the head and vertebral column,
   - the subclavian to the fore-limb.

From the left aortic arch, just as it unites with its fellow of the other side to form the dorsal aorta, or from the beginning of the dorsal aorta, there is given off the cœliaco-mesenteric to the stomach, intestine, liver, and spleen.

The dorsal aorta also gives off :—

the renal arteries to the kidneys, and the genital arteries to the reproductive organs ;

the inferior mesenteric to the large intestine ;

and then divides into two iliacs, each of which supplies bladder (hypogastric) and ventral body-wall (epigastric) and leg (sciatic).

III. The pulmo-cutaneous arch, the most posterior, corresponding to the fourth efferent branchial in the tadpole, gives off :—

the cutaneous artery to the skin,

the pulmonary artery to the lungs.

The Venous System.

I. Each superior vena cava is formed from the union of three veins, and each of these three is formed from two smaller vessels.

Superior vena cava.	External jugular.	Lingual from the mouth and tongue.
		Mandibular from the lower jaw.
	Innominate.	Internal jugular from the inside of the skull.
		Subscapular from the back of the arm and the shoulder.
	Subclavian.	Brachial from the arm.
		Musculo - cutaneous from the skin and sides of the body.

II. The inferior vena cava begins between the kidneys, and ends in the sinus venosus. Its components are as follows :—

Inferior vena cava.	Efferent renal veins from the kidneys.
	Genital veins from the reproductive organs.
	Efferent hepatic veins from the liver.

The renal portal system, by which venous blood from the posterior region passes through the kidneys on its way back to the heart, is as follows on each side:—

Renal portal system. — A posterior branch of the femoral vein from the hind-limb forms the renal portal vein, and receives the sciatic from the back of the leg, and the dorso-lumbar veins from the dorsal wall of the body, and oviducal veins in the female.

The anterior branch of the femoral vein is called the pelvic, and unites with its fellow of the opposite side, and gives origin to a median vein which runs to the liver—the anterior abdominal.

The hepatic portal system, by which venous blood from the posterior region and from the gut passes through the liver on its way back to the heart is as follows:—

Hepatic portal system. — Anterior abdominal vein, from the union of the two pelvics, receiving tributaries from the bladder, ventral body-wall, and truncus arteriosus.
Hepatic portal vein, from the union of veins from the stomach, intestine, and spleen.

III. The pulmonary veins which bring back purified blood from the lungs, unite just before they enter the left auricle.

Lymphatic System.—The lymph is a colourless fluid, which may be described as blood without red corpuscles. It is found in the spaces between the loose skin and the subjacent muscles, in the pleuro-peritoneal cavity in which heart, lungs, and other organs lie, in a sub-vertebral sinus extending along the backbone, and in special lymphatic vessels which pass fatty materials absorbed from the intestine into the venous system. There are two pairs of contractile "lymph-hearts" at two regions where the lymphatic system communicates with the veins. A pair lie posteriorly near the end of the urostyle; the other two lie between the transverse processes of the third and fourth vertebræ.

We must now return to the heart to consider how it is that

the blood is propelled from the ventricle along the proper channels. The right half of the ventricle being nearer the right auricle contains more impure blood, and it is from the right side of the ventricle that the truncus arteriosus arises. Therefore when the ventricle contracts, the blood which first fills the truncus is venous. It passes along the left side of a median longitudinal valve into the pulmonary valves—along the path of least resistance. As the pulmonary arteries become distended, the next quantum of blood—that which has been mixed in the middle of the ventricle—is driven forwards, and passes on the right side of the longitudinal valve into the aortic arches. "And, as the truncus becomes more and more distended, the longitudinal valve, flapping over, tends more and more completely to shut off the openings of the pulmonary arteries, and to prevent any blood from flowing into them. Finally, the last portion of blood from the ventricle, representing the completely arterialised blood of the left auricle, which is the last to arrive at the opening of the truncus, passes into the carotid trunks and is distributed to the head." (The last two sentences are quoted from the textbook of Practical Biology, by Huxley and Martin, Howes and Scott.)

Spleen, Thyroid, and Thymus.—The spleen, whose function is probably, as in some other animals, concerned with blood-making, is a small red organ lying in the mesentery near the beginning of the large intestine. The thyroid, of uncertain significance, is represented by two little bodies near the roots of the aortic arches. The thymus, perhaps originally associated with residues of branchial clefts, lies on each side just behind the angle of the lower jaw.

Respiratory System.—The larval frog breathes at first through its skin, then by external gills, and, finally, by internal gills. The adult frog breathes chiefly by its lungs, but some cutaneous respiration is still retained, for even without its lungs a frog may live for some time.

The lungs arise as outgrowths of the œsophageal region of the gut, and are developed some time before they come into use. They are connected with the back of the mouth, as we have already noticed, by a short laryngo-tracheal tube, whose slit-like aperture is the glottis. Each lung is a transparent oval sac, with muscle-fibres in its

walls. The cavity is lessened by the spongy nature of the internal walls, which form numerous little chambers bearing the fine branches of blood-vessels.

In respiration, the mouth is kept shut, and air passes in and out through the nostrils. A frog will die of asphyxia if its mouth be artificially kept open for a considerable time. When the floor of the mouth is lowered, and the buccal cavity thus increased, air passes in. When the elastic lungs and the muscles of the sides of the body contract, air passes out. When the nostrils and also the opening of the gullet are shut, and the floor of the mouth at the same time raised, air is forced through the glottis into the lungs.

Excretory System.—The paired kidneys are elongated organs situated dorsally and posteriorly in the region of the urostyle. The waste-products which they filter out of the blood pass backward by two ureters which open separately on the dorsal wall of the cloaca, without any communication with the bladder. The ureter is seen as a white line along the outer side of each kidney. In the male each ureter functions also as the duct of a testis. On the surface of each kidney is a longitudinal yellowish streak, an adrenal gland of unknown significance, and little spots mark ciliated apertures or nephrostomes, which remain as communications between the abdominal cavity and the renal veins, though perhaps they are in embryonic life connected with the urinary tubules.

Reproductive System.—The males are readily distinguished from the females by the swollen cushions on the innermost digits of the hand, and there are some other slight external differences. The breeding season begins in spring, and then the males are often heard trumpeting to their mates. The male clasps the female with his fore-limbs, and retains his hold for several days, fertilising the ova as they pass out into the water.

The paired testes are oval yellowish bodies lying in front of the kidneys; the spermatozoa pass by vasa efferentia through the anterior part of the kidney into the ureter or Wolffian duct, which thus functions as a vas deferens. In the male of *R. esculenta*, the vas deferens is dilated for some distance after leaving the kidney; in *R. temporaria* it bears

on its outer side near the cloaca a dilated glandular mass or "seminal vesicle." In the males rudiments of the Müllerian ducts are sometimes seen.

The paired ovaries when mature are large plaited organs, bearing numerous follicles or sacs containing the pigmented ova. The ripe ova are liberated into the body-cavity, and moved anteriorly towards the heart near which the oviducts open. These oviducts are long convoluted tubes, anteriorly thin-walled and straight, then glandular and coiled, terminally thin-walled and dilated. In the median part, the ova are surrounded with gelatinous stuff; the terminal uterine parts open on the dorsal wall of the cloaca. In the females the Wolffian ducts act solely as ureters. There are occasional variations in the nature of the reproductive organs, and sometimes the hermaphrodite stage through which the tadpoles pass, is to some extent retained, causing partial hermaphroditism. Attached to the anterior end of the reproductive organs, are yellow lobed "fatty bodies." They are always largest in the males. It has been suggested that they contain stores of reserve material, which is absorbed at certain seasons. They seem to be fatty degenerations of the anterior part of the genital ridges. The head-kidney or pronephros persists for some time in the embryo, but eventually degenerates. It does not seem to have anything to do with the fatty bodies.

Development of the Frog.—The ripe ovum contains a considerable quantity of yolk which has sunk towards one pole. The upper hemisphere contains much black pigment, the lower is not pigmented. If the ovum be artificially fixed so that the yolk-laden part is uppermost, the heavier material will again sink downwards. Round the egg there is a sphere of clear gelatinous stuff, which swells in the water. Before the liberation of the eggs, nuclear changes occur which seem to correspond to the formation of polar bodies.

Fertilisation takes place, as we have already mentioned, immediately after the liberation of the eggs from the mother frog. The spermatozoa, which exhibit the usual features of male elements, work their way through the gelatinous envelopes of the ova, and one fertilises each ovum. The segmentation which follows is total, but unequal, resulting in a ball of cells, those of the upper hemisphere being smaller

and more numerous than those below. Sections show a small segmentation cavity within. The upper layer cells gradually spread round and enclose the lower. But at one point, where upper and lower cells meet, an invagination of upper layer cells takes place. This invagination represents the formation of a gastrula; the cavity formed is the embryonic gut or archenteron, its roof is formed from invaginated cells, its floor from yolk-laden cells; the opening or blastopore of the invagination corresponds in position to the anus. The cells, several rows deep, which surround the outside, and were originally those of the upper hemisphere, are epiblastic; the invaginated layer establishes the hypoblast; between the two, especially about the lips of the blastopore, the mesoblast soon appears. This stage, in which the three germinal layers are established, is reached about the fifth or sixth day after fertilisation.

Thereafter, definite signs of the embryo begin to appear. Along the mid-dorsal line of the epiblast, a neural plate is differentiated, whose edges become raised and folded over, forming the medullary groove, which becomes the medullary or neural canal. A communication between this neural canal above and the archenteron below, is retained in the region of the blastopore. It is known as the neurenteric canal. Internally, the archenteron becomes larger and more definite, and its extension causes the segmentation cavity to disappear. Along the mid-dorsal line of the archenteron, a differentiation of hypoblast establishes the notochord. On each side of this lie segments of mesoblast, which used to be called protovertebræ, while inferiorly the mesoblast has divided into two layers, an outer somatic applied to the epiblast, an inner splanchnic investing the archenteron, the space between them being the body-cavity. About a fortnight after hatching, the form of the body is beginning to be distinct. Soon afterwards, the embryo begins to move its tail within the surrounding jelly, external gills grow out from the two hindmost of the four visceral arches, the mouth appears as an oval blind pit, two suckers lie just behind it, the eyes have been budded out from the brain and are showing themselves externally, the surrounding mucus disintegrates, and the embryo jerks itself away from it.

At this stage we may briefly summarise the history of the germinal layers.

The epiblast or ectoderm gives origin to the following structures:—
- The central nervous system and its outgrowths, the nerves, the optic cups, the pineal or parietal eye, part of the hypophysis;
- The epidermis and its ingrowths, which form the lens, the ear-sac, the nasal sac, the stomatodæum.

The hypoblast or endoderm gives origin to the following structures:—
- The lining of the mid-gut, and of its outgrowths, such as gill-clefts, lungs, liver, pancreas, and allantoic bladder;
- The notochord.

The mesoblast or mesoderm gives origin to the following structures:—
- The dermis or cutis, the muscles, the skeleton, the vascular system, besides aiding in the formation of organs, such as eyes and lungs, the essential parts of which are due to the other layers.

We may divide the development of the frog into three periods; the first ends with the hatching, the second includes the time between the hatching and the final metamorphosis, the third is the period of metamorphosis when the characteristic features of the adult are attained. We have summarised the first chapter of the history, let us now turn to the second.

The young tadpoles are still without an open mouth. They live on the still unexhausted capital of yolk which has been absorbed into the gut. Behind the indimpling which marks the incipient mouth, is a paired sucker, by which, when tired, the tapdoles fix themselves to water-weeds. In a few days, however, they gain a mouth, which is "bordered by a pair of horny jaws, and fringed with fleshy lips provided with horny papillæ." The whole arrangement reminds us of the lamprey's mouth.

Milnes Marshall and E. J. Bles have observed the strange fact that for a period commencing shortly before the opening of the mouth, and lasting some little time after the opening is effected, the œsophagus is solid. It is also remarkable, as these investigators point out, that the tadpole undergoes a distinct increase in bulk prior to the opening of the mouth, in explanation of which it is suggested that nutriment, such as the jelly of the spawn, may be absorbed by the cells of the sucker.

Having acquired a mouth, the tadpoles hungrily feed on water-weeds; the hitherto short alimentary canal becomes elongated and coiled like a watch-spring. About the time

when the mouth is opened, and the blastopore, which seems to be plugged with yolk, is replaced by a cloacal aperture, four gill-clefts open from the pharynx to the exterior. The external gills shrivel, and are replaced by an internal set, enclosed in a fold of skin forming a gill-chamber. Eventually this gill-chamber is closed, all but a single exhalent aperture on the left side. Through this aperture the water which is taken in by the mouth passes outwards, having washed the gills on its way.

Here let us summarise the relations of the visceral arches, branchial clefts, and blood-vessels.

ARCHES.	CLEFTS.	AORTIC ARCHES IN THE EMBRYO.	AORTIC ARCHES IN THE ADULT.
Mandibular.		Vessels comparable to those of a branchial arch.	Only a trace persists.
	Eustachian tube.		
Hyoid.		As above.	Disappear entirely.
	First cleft.		
First Branchial.		First efferent branchial.	Carotid arch.
	Second cleft.		
Second Branchial.		Second ,,	Systemic arch.
	Third cleft.		
Third Branchial.		Third ,,	Atrophies.
	Fourth cleft.		
Fourth Branchial.		Fourth ,,	Pulmo-cutaneous.

The heart develops before the vessels of the visceral arches, and before the dorsal aorta. The auricle is at first single like that of a fish, but becomes divided by a septum. The dorsal aorta is at first paired. At an early stage in *R. temporaria*, the course of the circulation is like that of a fish,—from the truncus arteriosus to afferent branchial vessels, thence through the gills to the efferent branchial vessels, and then to the dorsal aorta. But by and by a direct connection is established between the afferent and efferent branchial vessels, so that blood can pass from the heart to the dorsal aorta without going through the gills. At the time of metamorphosis an increasing quantity of blood passes by this short-cut, increased work is thus thrown on the lungs as respiratory organs, and the gills gradually atrophy. (These facts are taken from a research by Professor Milnes Marshall and Edward J. Bles).

The tadpole thrives on its vegetarian diet, grows rapidly bigger and stronger, swims rapidly by means of its tail,

while the paired adhesive sucker is less and less used, and gradually disappears. The limbs bud forth, but the anterior pair, hidden by the gill-covers, do not become visible so soon as the posterior pair. When the tadpole is about two months old, it has attained to the structural level of the Dipnoan fishes; it still has internal gills, but the lungs have begun to be functional. The larvæ come often to the surface to breathe.

We may now pass over two or three weeks to the third chapter in the history, when the tadpole begins to undergo a remarkable metamorphosis. It rises above the structural level of a fish, and becomes definitely an amphibian. It ceases to feed on water-weeds. For a time it seems to fast, but it is really living on its own tail, from which wandering leucocytes absorb nutriment, and carry it to other parts of the body. A casting of the outer layer of the epidermis takes place. "The horny jaws are thrown off; the large frilled lips shrink up; the mouth loses its rounded suctorial form and becomes much wider; the tongue, previously small, increases considerably in size; the eyes, which as yet have been beneath the skin, become exposed; the fore-limbs appear, the left one being pushed through the spout-like opening of the branchial chamber, and the right one forcing its way through the opercular fold, in which it leaves a ragged hole." (Quoted from Milnes Marshall: *The Frog; an Introduction to Anatomy, Histology, and Embryology*, 3rd ed. Manchester and London, 1888.)

While these changes are in progress, and as the supply of food afforded by the tail begins to be exhausted, the tadpole recovers its appetite, but is now carnivorous, feeding on available animal matter, and even on its fellows. At this stage tadpoles will clean a skeleton beautifully, and Buckland describes them as showing a great avidity for animal food, crowding round a drowned kitten, and nibbling at the toes of little boys who wade in the pools.

With the change of diet, the abdomen shrinks, stomach and liver enlarge, the intestine becomes relatively narrower and shorter. The tail shortens more and more, and is at last completely absorbed; the hind-limbs lengthen; the animal leaps ashore—a small frog.

It seems that for a considerable time the tadpole is neither

male nor female, but hermaphrodite. Differences in nutritive and other conditions cause one kind of sexual organ to predominate over the other, and the tadpole becomes unisexual. In nature there are usually about as many males as there are females, but Yung has shown that by increasing the quality of the food given to young tadpoles from fish-flesh to beef, and from beef to frog-flesh, he could raise the percentage of females to about ninety.

In many respects the development of the tadpole is very interesting, but most of all because it is a recapitulation of that transition from aquatic to aerial respiration, which must have marked one of the most momentous epochs in the evolution of Vertebrates.

CLASSIFICATION OF AMPHIBIA.

Order ANURA or ECAUDATA.

The attainment of the adult form is associated with the loss of tail and gills. The body is broad. The long and very muscular hind-legs are powerful in leaping.

(*a*) The frog and its allies :—
The British frog (*Rana temporaria*), brown in colour, with a black patch on the side of the head :
the edible frog (*R. esculenta*), not indigenous in Britain, common on the Continent, greenish in colour, without the black patch :
the North American bull-frog (*R. catesbiana*), sometimes eight inches in length, with a very sonorous croak :
some Asiatic and African "tree-frogs," such as *Rhacophorus* and *Hyperolius* :
some toothless frogs, such as the American *Dendrobates*.

(*b*) Those allied to the toad, all toothless :—
the toads in the strict sense (*Bufo*), with poisonous skin :
the crimson-bellied *Bombinator igneus*, the Feuerkröte of Germany :
the obstetric toad—*Alytes obstetricans*, the male of which carries the eggs on his back and legs : *Hylodes* in tropical America, with rapid development without metamorphosis :
the South American *Ceratophrys*, of which some species have bony plates in the skin of the back : *Pelobates*, which like many others lives for the most part underground : the brightly coloured tree-toads, such as *Hyla*, with adhesive discs at the ends of the digits : *Nototrema*, with a dorsal egg-pouch in the females: *Liopelma hochstetteri*, the only Amphibian in New Zealand.

(*c*) The tongueless Surinam Toad (*Pipa americana*), in which the eggs develop in pouches on the back of the female; and the allied Ethiopian genus *Xenopus*, with a "tentacle" extending backwards on each side of the head.

Order Urodela or Caudata.

The tail persists in adult life; the body is elongated; the limbs are weak when compared with those of Anura.

(*a*) Forms like *Proteus*:—Two extant genera *Proteus* and *Necturus*, both with persistent gills. Several species of *Proteus* inhabit the water in the caves of Carinthia and Dalmatia in Austria. The gills persist, there are two pairs of limbs. The eyes are degenerate, the colours are pale, as we would expect in cave-animals. Two species of *Necturus* (or *Menobranchus*) occur in North America, in rivers and lakes, such as those of the Mississippi and Ohio basins. The pigment of the skin is well-developed.

(*b*) Forms like *Siren*:—Two extant genera, *Siren* and *Pseudobranchus*, both North American, both with persistent gills, with only the anterior limbs.

(*c*) Forms like the newts and salamanders:—The North American *Amphiuma*, with two pairs of rudimentary legs, with a slit persisting in adult life as a remnant of the gilled state: the largest living Amphibian *Megalobatrachus* or *Cryptobranchus maximus* of Japan and Tibet attains a length of three feet; *Amblystoma* and its gilled form the Axolotl; *Desmognathus fusca*, the common water salamander of the United States, with eggs laid in a wreath which one of the sexes twines round its body; *Salamandra maculosa* and *S. atra*, both European, both viviparous; the newts—*Triton* or *Molge*—of which *Triton alpestris* becomes sexually mature while still larval.

Order Gymnophiona or Apoda.

Worm-like or snake-like forms, subterranean in habit; without limbs or girdles or tail; with dermic scales concealed in the skin; in at least some forms, gills occur in early life; the eyes are rudimentary; peculiar "tentacles" are connected with the orbit, and are perhaps equivalent with "balancers," which occur in larval Urodela in front of the first gill-cleft. *Cæcilia* in West Africa, Malabar, South America; *Siphonops* in Brazil and Mexico; *Epicrium* in Ceylon; *Rhinatrema* in Cayenne; *Cæcilia compressicauda* is viviparous.

Order Labyrinthodontia or Stegocephala.

Extinct forms, occurring from Carboniferous to Triassic strata.

History.—It is likely that Amphibians were derived from a stock from which the Dipnoi and perhaps also the Elasmobranchs sprang. The order Labyrinthodontia or Stegocephala does not seem very homogeneous; it perhaps includes two or more distinct orders. Of extant forms, the Gymnophiona are more old-fashioned than the others. The modern types gradually appear in Tertiary times. Some of the extinct forms were gigantic.

Huxley has emphasised the following affinities between Amphibians and Mammals:—The Amphibia agree with Mammals in having two condyles on the skull; it is only in Amphibians that the articular element of the mandibular arch remains cartilaginous, while the quadrate ossification is small, and the squamosal extends down over it to the osseous elements of the mandible, thus affording an easy transition to the mammalian condition of those parts; the pectoral girdle of Mammals is as much amphibian as it is sauropsidian; the mammalian carpus is directly reducible to that of Amphibians.

There are many remarkable affinities between the Labyrinthodont Amphibians and an order of extinct Reptiles known as Anomodontia, and as the latter have also many affinities with Mammals, it is possible that both Mammals and Anomodonts diverged from an Amphibian stock.

CHAPTER XXIII.

REPTILES.

Class Reptilia.

The three highest classes of Vertebrates—Reptiles, Birds, and Mammals—are often distinguished as Amniota from Amphibians and Fishes, which are called Anamniota. These terms refer to the fact that the embryos of the three higher classes possess a very characteristic birth-robe—the amnion—with which another—the allantois—is always associated. It seems that the cloacal bladder of Amphibians is homologous with the allantois, but it is not utilised in embryonic life. We shall afterwards explain the nature of the amnion and the allantois, but meantime the possession of these may be recognised as characteristic of Reptiles, Birds, and Mammals. It is also important to notice that no Vertebrates above Amphibians breathe by gills even in early life, a fact in part explained by the development of the allantois, which secures the respiration of the embryo.

Of these three highest classes the first two are closely linked to one another. Different as they are in habit and external form, Reptiles and Birds are united by deep structural resemblances. These were first clearly recognised by Huxley, when he united the two classes as Sauropsida in contrast to Mammalia on the one hand, and Ichthyopsida (Amphibians and Fishes) on the other. But though this classification is very important, it must not be allowed to obscure the fact that Reptiles possess affinities with both Amphibians and Mammals. Let us, however, state some of the characters which Huxley recognised as distinctive of Sauropsida in contrast to Ichthyopsida and Mammalia.

SOME OF THE CONTRASTS BETWEEN ICHTHYOPSIDA, SAUROPSIDA, AND MAMMALIA.

ICHTHYOPSIDA. FISHES AND AMPHIBIANS.	SAUROPSIDA. REPTILES AND BIRDS.	MAMMALIA. MONOTREMES, MARSUPIALS, & PLACENTALS.
There is no amnion nor allantois, except in so far as the latter is represented by the cloacal bladder of Amphibians.	The amnion of the embryo forms a protective membrane; the allantois secures embryonic respiration, and sometimes helps in absorbing food.	The amnion forms in part a protective membrane, in part it aids the allantois in forming the placenta, which is developed in all Mammals except Monotremes and Marsupials.
Respiration is almost always discharged by gills, during early life at least.	Respiration is never discharged by gills.	Respiration is never discharged by gills.
The epidermic exoskeleton is slight or absent.	There is an epidermic exoskeleton of scales or feathers.	There is an epidermic covering of hair, in most cases well-developed. Mammary glands are developed in the females.
There is a system of lateral sense-organs, at least during early life.		
The vertebral column is often incompletely ossified; on the ends of the vertebral centra, etc., there are no separate ossifications or epiphyses. Much of the cartilaginous brain-box may persist; there is often a large parasphenoid; the basi-sphenoid is small or absent; the basi-occipital is at most incompletely ossified; the condyle may be single or double, and in the latter case is due to the ex-occipitals; at least four branchial arches are developed; there are usually several membrane bones around Meckel's cartilage. The sternum if present is not formed from the ventral ends of ribs.	There are no epiphyses to the bones; there is no separate parasphenoid in the adult; the basi-sphenoid is large; the occipital region is completely ossified; there is but one condyle which is formed from the basi-occipital and the ex-occipitals; in reptiles the pro-, epi-, and opisth-otic bones remain separate from one another and fuse with adjacent bones; in birds they fuse with one another, and with adjacent bones about the same time; the mandible consists of one cartilage bone—the articular—and five membrane bones, it articulates with the skull by means of the quadrate. The sternum is formed from the ventral ends of ribs.	There are epiphyses at the ends of the vertebral centra (except in Monotremes and Sirenia), and also at the ends of most of the bones; with two or three exceptions there are seven cervical vertebræ; the pro-otic unites with epi- and opisth-otic before the latter fuse with adjacent bones; there are two condyles, usually formed from the ex-occipitals, sometimes with the help of the basi-occipital; the mandible of the adult is a single bone, articulating with the squamosal; there are three characteristic auditory ossicles—malleus, incus, and stapes—which perhaps correspond to the articular, quadrate, and hyo-mandibular of lower Vertebrates. Except in Monotremes the coracoid is rudimentary; the sternum is homologous with that of Sauropsida.
There are but ten cranial nerves.	There are twelve cranial nerves, exc. in snakes.	There are twelve cranial nerves.
The gut often ends in a cloaca.	The gut always ends in a cloaca.	Only in Monotremes is there a true cloaca.
The heart is two- or three-chambered; there are at least two persistent aortic arches; the red blood-corpuscles are oval and nucleated.	The heart is three- or four-chambered; in birds there is one aortic arch (to the right), in reptiles there are at least two aortic arches; the red blood-corpuscles are oval and nucleated.	The heart is four-chambered; there is one aortic arch (to the left); the red blood-corpuscles are non-nucleated and almost always circular; a muscular diaphragm separates thorax from abdomen.
The great majority are oviparous.	Except a few reptiles all are oviparous.	Except in Monotremes, all are oviparous.
The ova are generally numerous, with holoblastic or meroblastic segmentation.	The ova are large, with much yolk, usually with a calcareous shell, with meroblastic segmentation.	Except in Monotremes, the ova are small, with little or no yolk, with holoblastic segmentation.

Again we shall virtually quote from Huxley in noting some of the distinctions between Reptiles and Birds :—

REPTILES.	BIRDS.
The exoskeleton consists of horny epidermal scales, or of bony dermal scutes, or of both.	There is an outer covering of feathers, and though there may be a few scales there are never scutes.
The centra of the vertebræ are rarely like those of birds.	The centra of the vertebræ have usually a peculiar terminal curvature.
When there is a sacrum, its vertebræ (usually two in number) have large expanded ribs, with the ends of which the ilia articulate.	The two sacral vertebræ have no expanded ribs, they fuse with others to form a long composite sacrum.
The cartilaginous sternum may become bony, but is not replaced by membrane-bones, unless perhaps in Pterodactyls.	The cartilaginous sternum is replaced by membrane-bones from several centres.
When there is an interclavicle, it remains distinct from the clavicles and sternum.	When there is an interclavicle, it is confluent with the clavicles.
The hand has more than three digits, and at least the three radials are clawed.	The hand has not more than three digits, and at most two radials are clawed. The fore-limbs are modified as wings; some carpals fuse with the metacarpals.
In living reptiles the ilia are prolonged farther behind than in front of the acetabulum; the pubes slope downward and forward; there are pubic and ischiac symphyses.	The ilia are greatly prolonged in front of the acetabulum, the inner wall of which is membranous. The pubes slope backwards, parallel with the ischia; only in *Struthio* is there a pubic symphysis, only in *Rhea* is there an ischiac one.
There are often five toes; the tarsals and the metatarsals remain distinct.	There are not more than four toes; the proximal tarsals unite with the tibia, forming a tibio-tarsus; the first metatarsal if present is free, but the three others are fused to one another and to the distal tarsals, forming a tarso-metatarsus.
At least two aortic arches persist; only the Crocodilia have a structurally four-chambered heart; more or less mixed blood always goes to the posterior body.	There is but one aortic arch, to the right; the heart is four-chambered; the blood sent to the body is purely arterial.
The blood is cold.	The blood is hot.
The optic lobes lie on the upper surface of the brain.	The optic lobes lie on the sides of the brain.
	The lungs have associated air-sacs.
	The sutures between the bones of the skull are usually obliterated at an early stage.
	The right ovary atrophies.

There are five orders of living Reptiles, namely, Chelonia (tortoises and turtles); Rhynchocephalia, of which the New Zealand "lizard" *Hatteria* is the only surviving representative; Lacertilia (lizards), Ophidia (snakes), and Crocodilia (crocodiles, alligators, and gavials).

But the number of orders is greatly increased when we take account of those extinct Reptiles, which are not refer-

able to any of the types now represented on the earth. It is still uncertain how the extinct types of Reptiles should be arranged, but many authorities recognise the following orders:—Anomodontia, Sauropterygia, Ichthyopterygia, Dinosauria, Ornithosauria. To these we shall afterwards refer.

Order CHELONIA. Tortoises and Turtles.

The body is compact and broad in the region of the trunk. There is a dorsal and a ventral shield, within the shelter of which the head and neck, tail and limbs, can be more or less completely retracted.

The dorsal shield or carapace is formed from the neural spines of the vertebræ, from the expanded ribs, and from a series of marginal plates around the outer edge.

The ventral shield or plastron consists of nine plates—a median anterior piece and four pairs of plates behind it.

Overlapping, but in no way corresponding to the bony plates, are epidermic horny plates of "tortoise-shell," which though very hard are not without sensitiveness, numerous nerves ending upon them.

The jaws are covered by a horny sheath, and are without teeth, though rudiments of these have been seen in some embryos.

The average life of Chelonians is sluggish. Perhaps this is in part due to the way in which the ribs are lost in the carapace, for this must tend to make respiration less active.

All are oviparous. The eggs have firm usually calcareous shells.

Some Peculiarities in the Skeleton of Chelonia.

The dorsal vertebræ seem to be without transverse processes, and along with the ribs are for the most part immovably fused in the carapace. The tail and the neck are the only flexible regions.

Dr Berry Haycraft has investigated the development of the carapace, and has been good enough to give me the following brief summary of his results.

If we compare a very early embryo turtle with that of a crocodile, we notice the following difference:—In the crocodile, each cartilaginous

rib is completely invested by a tubular sheath of young connective tissue, and in the intercostal spaces are distinct muscle plates. In the turtle the cartilaginous ribs are simply embedded in young osteogenetic tissue, which forms the whole of the body wall, extending superficially up to the skin. As development proceeds in the crocodile, the tubular sheath of connective tissue (periosteum) investing each cartilaginous rib, grows in size, and forms bone (the rib) anterioryl, the cartilage being absorbed. Thus we get the adult cylindrical rib, separated from its neighbours by the intercostal muscles, developed from the muscle plates. In the green turtle bone begins to form upon the rib cartilage, the latter subsequently being absorbed, but as there is no investing periosteal sheath, this formation of bone spreads out on all sides, right up to the skin superficially, and as far as the neighbouring growths laterally, to form the solid bone of the carapace. In the mud turtles, the growth of bone which is extending laterally from each cartilaginous rib, does not meet its neighbour, for already the intercostal tissue has partly become differentiated into fibrous tissue, and a fibro-osseous carapace results. In the green turtle, the rib cartilage, at both its distal and proximal ends, is invested by true periosteum, which causes in these parts the formation of cylindrical bone.

What then is a costal plate?

It is more than a rib; it is a rib, which, in its development, has spread into and involved the surrounding intercostal tissue.

Is it an intramembranous or intracartilaginous bone? We now know that all bones are developed through the agency of membranes, and that the humerus, for example, an intracartilaginous bone, is eventually formed entirely from its membranous periosteum. It differs from the scapula (a membrane-bone) in this respect, that *it was at one time represented by cartilage*, while the scapula was not. A membrane-bone is therefore not a bone developed from a membrane, for every bone in the body is now known to be so formed, *it is a bone whose place was never represented by cartilage.*

If we accept this view of an intramembranous and intracartilaginous bone, a view forced upon us by modern inquiry, then the costal plate is an intracartilaginous bone, and comes out in its proper contrast from the marginal and plastron plates which are not preforned in cartilage. Hoffmann, not appreciating the general facts relating to bone development, argues that the costal plates are intramembranous because membranes enter into their *formation*. The neural plates may be looked upon as similar in their origin to the costal plates, bone encrusting the cartilaginous vertebræ, and then extending into the tissue between neighbouring spinous processes, and superficially up to the tissue which has differentiated into the thin layer of connective tissue, which is subscutal in its position.

The ventral shield or plastron consists of dermal bones; according to some the three anterior pieces represent clavicles and interclavicle.

The cervical vertebræ have at most little rudiments of ribs, are remarkably varied as regards their articular faces, and give the neck many possibilities of motion. There are no lumbar vertebræ.

The bones of the skull are immovably united; there are no ossified alisphenoids, but downward prolongations of the large parietals take

their place; neither presphenoid nor orbitosphenoids are ossified; there are no distinct nasal bones in modern Chelonians; the premaxillæ are very small; there are no teeth; there is a complete bony palate formed in great part from the junction of the pterygoids with the basisphenoid and with one another.

There is no sternum.

The pectoral girdle on each side consists of a dorsal scapula attached to the carapace, a ventral coracoid bearing terminally a small epicoracoid, and anterior to the coracoid a "precoracoid."

The pelvic girdle consists of dorsal ilia attached to the carapace, anterior pubes fused in a symphysis, and posterior ischia similarly fused.

The girdles originally lie in front of, or behind the ribs, but are overarched by the carapace in the course of its development.

Some Peculiarities in the Organs of Chelonia.

The brain of the adult shows a slight curvature. In Chelonians and in all higher animals except serpents, there are twelve cranial nerves, for in addition to the usual ten, a hypoglossal to the tongue, and a spinal accessory to cervical muscles are ranked as the eleventh and twelfth.

The gullet often bears internally pointed horny papillæ directed downwards. There are blind pockets or anal bursæ connected with the cloaca.

The heart is three-chambered, but an incomplete septum divides the ventricle into a right portion from which the pulmonary arteries and the left aortic arch arise, and a left portion from which the right aortic arch issues. From the right aortic arch, which contains more pure blood than the left, the carotid and subclavian arteries are given off. The left aortic arch gives off the cœliac artery before it unites with the right.

Unlike other Reptiles, the Chelonians are said to have no renal portal system.

The lungs are attached to the dorsal wall of the thorax, and have only a ventral investment of peritoneum; each is divided into a series of compartments into which branches of the bronchus open. There is a slight muscular diaphragm.

In the males, the kidney, the epididymis, and the testis, lie adjacent to one another on each side. The males have a grooved penis attached to the anterior wall of the cloaca. There is a urinary bladder.

Classification of Chelonia.

Order I. ATHECATA.

Sphargidæ, leather-turtles, with flexible carapace. *Sphargis coriaceus*, the only living species, the largest modern Chelonian, sometimes

measuring six feet in length. It is widely but now sparsely distributed in tropical and temperate seas, and is said to be herbivorous.

Order 2. TESTUDINATA.

Chelonidæ, marine turtles, with fin-like feet, and partially ossified carapace. They occur in intertropical seas, and bury their soft-shelled eggs on sandy shores. The green turtle (*Chelone viridis*) is much esteemed as food; the hawk's-bill turtle (*Caretta imbricata*) furnishes much of the commercial tortoise-shell.

Testudinidæ, land tortoises, with convex perfectly ossified carapace and feet adapted for walking. They are found in the warmer regions of both the old and the new world, but not in Australia. In diet they are vegetarian. The common tortoise (*Testudo græca*), and the exterminated giant tortoises of the Mascarene and Galapagos Islands are good representatives.

Chelydidæ, fresh-water tortoises, more or less aquatic, with perfectly ossified carapace, and feet with sharp claws. Examples—*Chelys fimbriata*, from Brazil and the Guianas, with warty growths of deceptive appearance; *Emys orbicularis* common in S. Europe; *Chelydra* and *Macroclemmys*, the aquatic terrapenes of N. America.

Trionychidae, fresh-water turtles, with depressed carapace covered with soft skin, with webbed digits. Each foot has sharp claws on the three inner digits. They are carnivorous in habit. Examples—*Trionyx, iavanicus, gangeticus, niloticus*, from Java, the Ganges, and the Nile respectively.

Order RHYNCHOCEPHALIA.

The only living representative of this order is the New Zealand "Lizard"—*Hatteria* or *Sphenodon punctatus*, the Tuatara of the Maoris. Lizard-like in appearance, it measures from one to two feet in length, has a compressed crested tail, is dull olive-green spotted with yellow above and whitish below. It is fast becoming very rare, but is still found in some small islands off the New Zealand coast. It lives in holes among the rocks or in small burrows, feeds on small animals, and is nocturnal in habit.

The skull, unlike that of any lizard, has an ossified quadrato-jugal, and therefore a complete infra-temporal arcade; the quadrate is firmly united to pterygoid, squamosal, and quadrato-jugal; the pterygoids meet the vomer and separate the palatines; there are teeth on the palatine in a single longitudinal row, parallel with those on maxilla and mandible, and the three sets seem to wear one another

away; there is also a single tooth on each side of a sort of beak formed by the premaxillæ; the nares are divided.

The vertebræ are biconcave, as in geckos among lizards and in many extinct Reptiles. Some of the ribs bear uncinate processes, as in Birds; as in crocodiles, there are "abdominal ribs," ossifications in the sub-cutaneous fibrous tissue of the abdomen.

The pineal or parietal eye, which reaches the skin on the top of the head, is less degenerate than in other animals, retaining, for instance, distinct traces of a complex retina.

Near the living *Hatteria*, the Permian *Palæohatteria*, the Triassic *Hyperodapedon*, and some other important types may be ranked. Along with these may be included the remarkable *Proterosaurus* from the Permian, though Seeley establishes for it a special order Proterosauria as distinguished from Rhynchocephalia. On page 6, I have used the term Proterosauria as if it were equivalent to Rhynchocephalia. According to Baur, quoted by Nicholson and Lydekker, "the Rhynchocephalia, together with the Proterosauria, to which they are closely allied, are certainly the most generalised group of all Reptiles, and come nearest, in many respects, to that order of Reptiles from which all others took their origin."

Order LACERTILIA—Lizards.

This order occupies a somewhat central position among Reptiles.

The body is usually well-covered with scales.

In most, both fore- and hind-limbs are developed and bear clawed digits, but either pair or both pairs may be absent. The shoulder- and hip-girdles are always present, in rudiment at least.

Unlike snakes, lizards have non-expansible mouths, and almost always movable eyelids and external ear openings.

The teeth are fused to the edge or to the ridge of the jaws, never planted in sockets.

The tongue, broad and short in some, *e.g.*, Geckos and Iguanas, long and terminally clubbed in Chamæleons, is oftenest a narrow bifid organ of touch.

The opening of the cloaca is transverse.

There is a urinary bladder and a double penis.

Most are oviparous, but in a few the eggs are hatched within the body.

They are usually active agile animals, beautifully and often protectively coloured.

The caudal region is often very brittle ; lost tails and even legs may be regenerated.

The food generally consists of insects, worms, and other small animals, but some prey upon larger animals, and others are vegetarian.

Most are terrestrial, some arboreal, a few semi-aquatic, and there is one marine form.

Lizards are most abundant in the tropics, and are absent from very cold regions.

Some Peculiarities in the Skeleton of Lizards (mostly quoted from Huxley).

The epidermic exoskeleton of scales is sometimes, as in *Cyclodus*, associated with scutes or ossifications in the dermis. In Geckos and Amphisbænas there is hardly any exoskeleton.

Except the Geckos, all living Lizards have procœlous vertebræ. The sacral vertebræ, two or rarely three in number, are not fused. Underneath the vertebræ, in the anterior part of the tail, there are usually special " chevron " bones. In many cases there is an unossified septum across the middle of each caudal vertebræ, and it is across this that the tail so readily breaks.

In the skull, there is an interorbital septum except in Amphisbænas, there are no alisphenoids nor completely ossified presphenoid or orbito-sphenoids, there is usually an unossified parietal foramen on the roof of the skull, in most an epipterygoid (or " columella ") runs from the parietal to the pterygoid, in most there are prominent parotic processes formed from prolongations of the opisthotics, pro-otics and ex-occipitals, with the outer end of one of these processes the quadrate articulates, and is usually movable, the fronto-parietal region is often slightly movable on the occipito-sphenoidal part, the quadrato-jugal is usually represented by ligament only, from the union of the palatine and pterygoid a transverse bone extends to the maxilla, the two rami of the lower jaw are in most cases firmly connected.

Teeth occur on the premaxillæ, maxillæ, and dentaries, and sometimes also on palatines and pterygoids. They generally become fused to the bones which bear them. When they are attached by their bases to the ridge of the jaw, the dentition is described as acrodont ; when they are attached by their sides to the side of the jaw, the dentition is described as pleurodont.

"When the pectoral arch is complete, it consists of a supra-scapula, scapula, coracoid (with precoracoid and epicoracoid elements), and two clavicles, united by an interclavicle, which lies in the groove of the sternum."

In the pelvic girdle, the ilia are movably articulated to cartilages at the end of the sacral ribs, the pubes (usually with a pre-pubic process) and the ischia meet in median symphyses.

Further Notes in regard to Lizards.

Many Lizards, such as the Chamæleons, exhibit in a remarkable degree the power of rapidly changing the colour of their skin. This is due to the fact that the pigment-cells or chromatophores contract or expand under nervous control. The change of colour is sometimes advantageously protective, but it seems often to be merely a reflex symptom of the nervous condition of the animals.

In a few cases, *e.g.*, some of the skinks, there are minute dermal ossifications beneath the scales.

In some, there are two aortic arches on each side, uniting with one another and forming the dorsal aorta. A single epigastric vein collects blood from the abdominal walls and from the bladder, and enters the liver, like the anterior abdominal of the frog.

In some Lizards (Chamæleons and Geckos), there are small air-sacs connected with the lungs, suggesting those of Birds.

The right reproductive organ tends to be larger and in front of the left. In many of the males, the Wolffian body is well-developed. Viviparous, or what is clumsily called ovo-viviparous, parturition is well illustrated by *Zootoca viviparus*, *Anguis fragilis*, *Seps*, etc., but most lay eggs with more or less calcareous shells. In *Trachydosaurus* and *Cyclodus*, the embryo seems to absorb food from the wall of the uterus. It is likely that Lacertilians existed in Permian ages, but their remains are not numerous before the Tertiary strata.

Many instructive illustrations of evolutionary change are afforded by lizards. Thus there are numerous gradations in the reduction of the limbs, from a decrease in the toes to entire absence of limbs. The diverse forms of tongue and the varied positions of the teeth, are also connected by gradations. From the variations of the wall-lizard (*Lacerta muralis*), Eimer elaborated most of his theory of evolution.

Classification of Lizards.—The order Lacertilia is usually divided into about a score of families.

In the geckos (Geckonidæ) the vertebræ are biconcave or amphicœlous, the tongue is short and fleshy, the eyelids are rudimentary, the teeth are pleurodont, the toes bear numerous plaits, by means of which they adhere to smooth surfaces. The Geckos have been observed to eat their own young and even their own tails. The name Gecko indicates their call. Examples:—*Platydactylus mauritanicus* (S. Europe), *Hemidactylus* in most warm countries, *Ptychozoon*, with lateral webs of skin which serve as parachutes.

The Agamas (Agamidæ) are acrodont lizards common in the eastern

hemisphere. Examples:—*Agama; Draco*, with the skin extended on long prolongations of five or six posterior ribs; *Chlamydosaurus*, an Australian lizard, with a large scaled frill around the neck; *Moloch*, another Australian form bristling with sharp spikes.

The Iguanas (Iguanidæ) are pleurodont lizards, represented in the warmer parts of the New World. Examples:—*Iguana*, an arboreal lizard, with a large distensible dewlap; *Amblyrhynchus* or *Oreocephalus cristatus*, a marine lizard confined to the Galapagos Islands; *Basiliscus*, in S. Mexico, with none of the marvellous qualities of the mythological basilisk; *Anolis*, the American chamæleon, with powers of rapid colour-change; *Phrynosoma*, the American "horned-toad," with numerous horny scales.

The slow-worms (Anguidæ), are limbless lizards, with serpentine body, long tail, rudimentary girdles and sternum. The British species, *Anguis fragilis*, is neither blind nor poisonous; the tail breaks very readily; the young are hatched within the mother. The American "glass-snake"—*Opheosaurus ventralis*—is in many ways like our slow-worm.

The poisonous Mexican lizard (*Heloderma suspectum*) measures over a foot in length, and is covered with bead-like scales. Its bite is poisonous, and rapidly fatal to small Mammals. It is interesting to find poisonous powers like those of many serpents exhibited by this exceptional lizard.

The water-lizards (Varanidæ) are large semi-aquatic forms of carnivorous habit, most at home in Africa, but represented also in Asia and Australia. The Monitor of the Nile, *Varanus niloticus*, may attain a length of five or six feet, and is noteworthy because of its fondness for the eggs and young of Crocodiles.

The family Teiidæ includes many New World pleurodont lizards, mostly terrestrial in habit, for examples *Teius teguexim*, the variegated lizard of tropical Brazil, sometimes measuring five feet in length; *Ameiva dorsalis*, the common ground-lizard of Jamaica.

The Amphisbænidæ are degenerate subterranean lizards, without limbs, with rudimentary girdles, with no sternum, with small covered eyes, with hardly any scales. The sooty Amphisbæna (*A. fuliginosa*), at home in the warmer parts of S. America, is the commonest species.

The Lacertidæ are Old World acrodont lizards, such as *Pseudopus* (Europe and S. Asia), *Lacerta viridis*, the green lizard of Jersey and S. Europe, *L. agilis*, the British grey lizard, *L. muralis* abundant about ruins in S. Europe, *L.* or *Zootoca vivipara*, the British scaly lizard.

The Scincidæ are common in tropical countries, *e.g.*, *Scincus*, *Cyclodus*, *Seps*, *Acontias* (without limbs), *Oligosoma* (abundant in the Southern States of America), *Eumeces* (common in America and elsewhere).

The Chamæleons (Chamæleontidæ) are very divergent lizards, mostly African. There is one genus *Chamæleo*. The head and the body are compressed; the scales are minute; the eyes are very large and movable, with circular eyelids pierced by a hole; the tympanum is hidden; the tongue is club-shaped and viscid; the digits are divided into two sets, and well-adapted for prehension; the tail is prehensile; the power of colour-change is remarkably developed.

The Chamæleons exhibit numerous anatomical peculiarities. As in the Amphisbænas, there is no epipterygoid nor interorbital septum. The pterygoid does not directly articulate with the quadrate which is ankylosed to the adjacent bones of the skull.

Order OPHIDIA. Serpents or Snakes.

The elongated limbless form of snakes seems at first sight almost enough to define this order from other Reptiles, but it must be carefully noticed that there are limbless lizards, limbless amphibians, and limbless fishes, which resemble serpents in shape though very different in internal structure. For the external shape seems in great part an adaptation to the mode of life, to the habit of creeping through crevices or among obstacles. Even in the thin-bodied weasels is there not some suggestion of the serpent? Yet the limblessness of serpents is not a merely superficial abortion, for there is no pectoral girdle nor sternum, and never more than a hint of a pelvis.

The skin is covered with scales, which being simply folds of the epidermis have much coherence, and are periodically shed in a continuous slough. The scales on the head form large plates, and those on the ventral surface are transverse shields. There are no separate eyelids, but the thin transparent epidermis extends over the staring eyes. The nostrils lie near the tip of the head; there are no external ear-openings. In many cases there are odoriferous glands near the cloacal aperture.

The muscular system is very highly developed, and the limbless serpent, Owen says, "can outclimb the monkey, outswim the fish, outleap the zebra, outwrestle the athlete, and crush the tiger."

There are many remarkable peculiarities in the skeleton. The vertebræ are very numerous, some pythons having four hundred; they are procœlous, and are distinguishable only into a pre-caudal and caudal series.

All the pre-caudal vertebræ except the first—the atlas—have associated ribs, which are movably articulated and used as limbs in locomotion. In the caudal region, the transverse processes, which are elsewhere very small, take the place of ribs.

The serpent "literally rows on the earth, with every scale for an oar; it bites the dust with the ridges of its body." On a perfectly smooth surface it can make no headway, but in normal conditions the edges of the anterior ventral scales are fixed against the roughnesses of the ground, the ribs are drawn together first on one side then on another, the body is thus wriggled forward to the place of attachment, the front part shoots out as the hind part fixes itself, an anterior attachment is again effected, and thus the serpent flows onward. But this account of the mechanism of movement, does not suggest the swiftness or the beauty of what Ruskin calls "one soundless, causeless march of sequent rings, and spectral procession of spotted dust, with dissolution in its fangs, dislocation in its coils." "Startle it; the winding stream will become a twisted arrow;—the wave of poisoned life will lash through the grass like a cast lance."

One of the most distinctive characteristics of the skull, is the mobility of some of the bones. Many of the Ophidians swallow animals which are larger than the normal size of the mouth and throat. The mobility of the skull bones is an adaptation to this habit. Thus, the rami of the mandible are united by an elastic ligament; the quadrates and the squamosals are also movable, forming "a kind of jointed lever, the straightening of which permits of the separation of the mandibles from the base of the skull." The nasal region also may be movable. On the other hand, the bones of the brain-case proper are firmly united. The premaxillæ are very small and rarely bear teeth; the palatines are usually connected with the maxillæ by transverse bones, and through the pterygoids with the movable quadrates.

Teeth, fused to the bones which bear them, occur on the dentaries beneath, and above on the maxillæ, palatines, and pterygoids, and very rarely on the premaxillæ. The fang-like teeth of venomous serpents are borne by the maxillæ, and are few in number. Each fang has a groove or canal down which the poison flows. When the functional fangs are broken, they are replaced by reserve fangs which lie behind them. In the egg-eating African *Rachiodon* the teeth are rudimentary, but the inferior spines of some of the anterior vertebræ project on the dorsal wall of the gullet, and serve to break the egg-shells.

When a venomous snake strikes, the mandible is lowered, the distal end of the quadrate is thrust forward, this pushes forward the pterygoid, the pterygo-palatine joint is bent, the maxilla is rotated on its lachrymal joint, the fangs borne by the maxilla are erected into a vertical position, the poison gland is compressed by a muscle, and the venom is forced through the fang.

While there are no hints of anterior appendages, pythons, boas, and some other snakes, have rudiments of a pelvis and even small clawed structures which represent hind-legs.

Some of the peculiarities in the internal organs of Ophidia, may be connected with the elongated and narrow shape of the body. Thus one lung, usually the left, is always smaller than its neighbour, or only one is developed; the liver is much elongated; the kidneys are not opposite one another.

The brain presents no remarkable peculiarities; there are only ten cranial nerves; the sense of hearing is often slightly developed, and there is no tympanic cavity; the eyelids are fused and transparent; the bifid, mobile, retractile tongue is a specialised organ of touch.

The poison gland is a specialised salivary gland; the venom is useful in defence, and in killing the prey, which is always swallowed whole.

The heart is three-chambered, the ventricular septum being incomplete, as in all other Reptiles except Crocodilians.

There is a transverse cloacal aperture. In the males, a double saccular and spiny copulatory organ is eversible from the cloaca.

The British adder (*Pelias berus*) is viviparous, and so are a few others. The great majority are oviparous, but confinement and abnormal conditions may make oviparous forms, like the *Boa constrictor* and the British grass snake (*Tropidonotus natrix*), viviparous. The female python incubates the eggs.

Many Ophidians become lethargic during extremes of temperature, or after a heavy meal.

Though most abundant in the Tropics, snakes occur in most parts of the world. They are absent from many islands; thus there are none in New Zealand, and we all know that there no snakes in Iceland. Most are terrestrial

and symbolise the power of the earth, but not a few readily take to the water, and there are many habitual sea-serpents.

The serpent still bites the heel of progressive man, the number of deaths from snake-bite in India alone amounting to many thousands yearly, though there can be little doubt that the snakes are often innocent scape-goats.

True Ophidians first occur in Tertiary strata.

Classification of Ophidia.

Sub-order 1. Typhlopidæ. The lowest and most divergent Ophidians, occurring in most of the warmer parts of the earth, generally smaller than earthworms, usually subterranean burrowers, with eyes hidden under scales, with a non-distensible mouth, with teeth restricted either to the upper or to the lower jaw. "The palatine bones meet, or nearly meet, in the base of the skull, and their long axes are transverse; there is no transverse bone; the pterygoids are not connected with the quadrates" (Huxley).

Example :—*Typhlops*, British India.

In all other Ophidians, the palatines are widely separated, and their long axes are longitudinal; there are transverse bones connecting palatines and maxillæ; the pterygoids are connected with the quadrates.

Sub-order 2. Colubriformes (innocuous Snakes). The poison gland is not developed as such; the maxillary teeth are not grooved.

Examples :—The British smooth snake (*Coronella lævis*), the British grass snake (*Tropidonotus natrix*), the Pythons, the Boas. The Anaconda (*Boa murina*), which may attain a length of almost thirty feet, is the largest living Ophidian.

Sub-order 3. Colubriformes Venenosi.

Examples :—Cobras, *Naja tripudians* (Indian), *Naja haje* (African); the Hamadryad (*Ophiophagus elaps*), eating other snakes; Coral-snakes (*Elaps*, etc.); Sea-snakes (*Hydrophis*, etc.), with paddle-shaped tails.

Sub-order 4. Viperiformes.

Examples :—The British adder (*Pelias* or *Vipera berus*); the Rattle-snake (*Crotalus*), with a rattle formed chiefly from epidermic remnants of successive sloughings; the African Puff-adder (*Clotho arietans*).

Order CROCODILIA. Crocodiles, Alligators, Gavials.

The Crocodilians are carnivorous fresh-water reptiles of large size. They are now represented by three genera,—*Crocodilus*, *Alligator*, and *Gavialis*.

The skin bears epidermic scales, and underneath some of these there are bony dermic scutes.

The tail is laterally compressed and assists in swimming.

Teeth occur in distinct sockets in the premaxillæ, maxillæ, and dentaries.

In all modern Crocodilians, almost all the vertebræ are procœlous.

The skull has many characteristic features, such as the union of maxillæ, palatines, and pterygoids in the middle line on the roof of the mouth, and the consequent position of the posterior nares at the very back of the mouth.

Some of the ribs have double articulating heads, and bear uncinate processes somewhat like those of birds; transverse ossifications associated with the sub-cutaneous fibrous tissue of the abdomen form so-called abdominal ribs.

The heart is four-chambered; a muscular diaphragm partially separates the thoracic from the abdominal cavity.

The cloaca has a longitudinal opening. The males have a grooved penis.

The Crocodilians are oviparous. The eggs have firm calcareous shells, and are laid in holes in the ground.

Some of the Characteristic Features in the Skeletal System of Crocodilians.

(These notes on the skeleton are in great part taken from Huxley's Manual.)

Numerous transverse rows of sculptured bony plates or scutes, ossified in the dermis, form a dorsal shield. On the ventral surface the scutes are absent, except in some alligators, in which they are partially ossified. But besides and above the scutes, there are horny epidermic scales like those in other Reptiles. The hide is often used as leather.

The vertebral column consists of distinct cervical, dorsal, lumbar, sacral, and caudal vertebræ, all procœlous except the first two cervicals, the two sacrals, and the first caudal. In most of the pre-cretaceous Crocodilians, however, the vertebræ were amphicœlous. The centra of the vertebræ are united by fibro-cartilages, and the sutures between the neural arch and the centrum persist at least for a long time. Chevron bones are formed beneath the centra of many of the caudal vertebræ.

Many of the ribs have two heads—capitulum and tubercle—by which they articulate with the vertebræ. From seven to nine of the anterior dorsal ribs are connected with the sternum by sternal ribs, and from several of these anterior ribs cartilaginous or partially ossified uncinate processes project backwards. The so-called abdominal ribs have nothing

to do with ribs, but are ossifications in the fibrous tissue which lies under the skin and above the muscles. They form seven transverse series, each composed of several ossicles.

As to the skull, there is an interorbital septum with large alisphenoids; the presphenoid and orbitosphenoids are at best incompletely ossified; all the bones are firmly united by persistent sutures; both upper and lower temporal arcades are completely ossified; the maxillæ, the palatines, and the pterygoids meet in the middle line of the roof of the mouth, covering the vomers, and determining the position of the posterior nares—at the very back of the mouth; an epi-pterygoid connects parietal and pterygoid; an os transversum extends between the maxilla and the junction of palatine and pterygoid; the quadrate is large and immovable; there are large parotic processes; the tympanic cavity is completely bounded by bone; the teeth, which are borne by premaxillæ, maxillæ, and dentaries, are lodged in distinct cavities; beside and eventually beneath the teeth lie reserve "germs" of others.

Each ramus of the mandible consists, as in most Reptiles, of a cartilage-bone—the articular—working on the quadrate, and five membrane-bones—dentary, splenial, coronoid, angular, and surangular.

The hyoid region is very simple.

In the pectoral arch there are no clavicles nor epicoracoids, but there is a so-called interclavicle or episternum; the fore-limb is well though not strongly developed; there are five digits, webbed and clawed.

In the pelvic arch, large ilia are united to the strong ribs of the two sacral vertebræ; the pubes slope forward and inward and have a cartilaginous symphysis; the ischia slope backward and have a symphysis; ilia and ischia form almost the whole of the acetabulum. The hind-limbs bear four digits, webbed and clawed.

Some of the Characteristics of the various organs of Crocodilians.

The Crocodilians are seen to best advantage in the water, swimming by powerful tail-strokes. The limbs are too weak for very effective locomotion on land, the body drags on the ground, and the animals are stiff-necked. Although many, especially in their youth, feed on fishes and small animals, the larger forms lurk by the edge of the water, lying in wait for mammals of considerable size. These they grasp in their extremely powerful jaws, and drown by holding them under water. If the dead booty cannot be readily torn, it is often buried and left until it begins to rot. In connection with their way of feeding, we should notice several peculiarities of structure; as the nostrils are at the upper end of the snout, and the eyes and ears also near the upper surface, the Crocodilians can breathe, see, and hear, while the body is altogether immersed except the upper surface of the head; as the nostrils can be closed by valves, and the eyes by transparent third eyelids, and the ears by movable flaps, the head can be comfortably immersed; a flat tongue is fixed to the floor of the mouth, and the cavity of the mouth is bounded behind

by two soft transverse membranes which, meeting when the reptile is drowning its prey, prevent water rushing down the gullet; the posterior opening of the nostrils is situated at the very back of the mouth, and when the booty is being drowned, the Crocodilian keeps the tip of its snout above water, the glottis is pushed forward to meet the posterior nares, a complete channel for the passage of air is thus established, and respiration can go on unimpeded. For their shore work the Crocodilians prefer the darkness, but they often float basking in the sun, with only the tip of the snout and the ridge of the back exposed.

Glands with a secretion which smells like musk are usually developed on the margin of the lower jaw, at the side of the cloacal aperture, and on the posterior margins of the dorsal scutes. The musky odour is very strong during the pairing season, and when the animals are attacked.

In connection with the muscular system, the presence of what is often called an incipient diaphragm between the thoracic and the abdominal cavity is of interest.

The brain seems very small in relation to the size of the skull.

The eyes are provided with a third eyelid, as in most Reptiles, Birds, and Mammals; there are large lachrymal glands, but there is no special deceitfulness about "crocodile's tears."

The ears open by horizontal slits, over which lies a flap of skin; three Eustachian tubes—one median and one on each side—open into the mouth behind the posterior nares.

The nostrils also can be closed, and, as we have already noticed, their internal openings lie at the back of the mouth.

The stomach suggests a bird's gizzard, for it has strong muscular walls, and its pyloric end is twisted upward so as to lie near the cardiac part.

The heart is four-chambered, the septum between the ventricles being complete as in Birds and Mammals. But as the dorsal aorta is formed from the union of a left aortic arch containing venous blood, and a right aortic containing arterial blood, the blood which is driven to many parts of the body is "mixed blood," *i.e.*, blood partly venous, partly arterial, with some of its red blood-corpuscles carrying hæmoglobin and others oxy-hæmoglobin. At the roots of the two aortic arches there is a minute communication between them—the foramen Panizzæ.

Into the right auricle venous blood is brought by the two superior venæ cavæ and by the inferior vena cava. The blood passes through a valved aperture into the right ventricle, and is driven thence (*a*) by the pulmonary artery to either lung, or (*b*) by the left aortic arch to the body. From this left aortic arch, before it unites with its fellow on the right to form the dorsal aorta, is given off the great cœliac artery. The anterior viscera thus receive wholly venous blood from the heart.

The blood driven to the lungs is purified there, and returns by pulmonary veins to the left auricle. Thence it passes through a valved aperture into the left ventricle. Thence it is driven into the right aortic arch. From this the carotids to the head and the subclavians to the fore-limbs are given off. These parts of the body thus receive wholly arterial blood from the heart.

The venous blood returning from the posterior regions may pass

through the kidneys in a renal portal system, and thence into the inferior vena cava; or it may pass through the liver in a hepatic portal system, and thence by hepatic veins into the inferior vena cava; or some of it may pass directly into the inferior vena cava. The renal portal veins arise from a transverse vessel uniting the two branches of the caudal, but the latter are also continued forward as lateral epigastrics which enter the liver.

The temperature of the blood is not above that of the surrounding medium.

In regard to the respiratory system, we should notice that the lungs are invested by pleural sacs as is the case in Mammals.

The ureters of the kidneys, the vasa deferentia from the testes in the male, the oviducts from the ovaries in the female open into the cloaca, which has a longitudinal opening.

The eggs, which in size are like those of geese, have a thin calcareous shell, are buried in excavated hollows, and, warmed by the sun, hatch without incubation.

Of one species of crocodile it is known that the mother opens up the nest when the young, ready to be hatched, are heard to cry from within the eggs. The mothers take some care of the young, which require to be defended even from the appetite of the males.

Crocodiles are relatively sluggish, and fond of basking passively, sometimes hiding in the mud during the hot season. They are remarkable for the long continuance of growth, which does not seem to have so definite a limit as in most other animals.

Classification of Crocodilia.

(*a*) The true crocodiles, of the genus *Crocodilus*, occur in Africa, Southern Asia, tropical Australia, Central America, and the West Indies.

The Indian Crocodile (*C. porosus*) may measure about eighteen feet in length, and even larger forms have been recorded. The sacred African crocodile (*C. vulgaris*) is still formidably common in some of the fresh waters of tropical Africa.

The eggs and the young are often eaten by a mammal called the Ichneumon, and by a species of lizard. The adults have few enemies except man. They seem to live in friendly partnership with little birds (*Pluvianus ægypticus*), which remove parasites from the body, and in their familiarity almost justify the account which Herodotus gives of their cleaning the reptile's teeth.

(*b*) The Alligators, of the genus *Alligator*, are, with the exception of one Chinese species, confined to North and South America. In North America *A. mississippiensis*, in South America *A. sclerops*, are common.

(*c*) The gavials or gharials, of the genus *Gavialis*, are distinguished by their long narrow snout. In the Ganges and its tributaries, *G. gangeticus*, said to attain a length of twenty feet, is common. They feed chiefly on fishes. "Old males have a large cartilaginous hump on the extremity of the snout, containing a small cavity for the retention of air, by which means these individuals are enabled to remain under water for a longer time than females or young."

DIFFERENCES BETWEEN CROCODILES, ALLIGATORS, AND GAVIALS.

ALLIGATORS.	CROCODILES.	GAVIALS.
The head is short and broad.	Longer.	The snout is very long.
First and fourth lower teeth bite into pits in the upper jaw.	The first bites into a pit; the fourth into a groove.	First and fourth lower teeth bite into grooves in the upper jaw.
The union of the two rami of the lower jaw does not extend beyond the fifth tooth.	Not beyond the eighth.	The union extends at least to the fourteenth.
The nasal bones form part of the nasal aperture.	As in the alligator.	The nasal bones do not form part of the nasal aperture.
The teeth are very unequal.	Unequal.	Almost equal.
The scutes on the neck are distinct from those on the back.	Sometimes distinct, sometimes continuous.	Continuous.
All American, except one Chinese species.	Living in Africa, India, Australia, Cuba, S. America.	Living in India, Borneo, N. Australia.

History of Crocodilians.—These giant reptiles form a decadent order. Fossil forms are found in Triassic strata (*e.g.*, *Belodon*, *Parasuchus*, and *Stagonolepis*); their remains are abundant in Jurassic rocks. In Cretaceous strata, crocodilians with procœlous vertebræ first occur, the pre-Cretaceous forms having centra of the amphicœlous type. Huxley has worked out an "almost unbroken" series from the ancient Triassic crocodilians down to those of to-day.

Extinct Orders of Reptiles.

Reptilian fossils occur in Permian strata and thence onwards; most of the orders are represented in the Trias; the golden age of Reptiles was during Jurassic and Cretaceous ages.

Some of the modern Reptiles are indissolubly linked to very ancient progenitors, the Crocodilians of to-day to those of the Trias, the New Zealand "lizard" to the Triassic Rhynchocephalia, but no Reptilian genus has persisted age after age as *Ceratodus* has done among Fishes.

On the other hand, many types once abundant have long since disappeared. These extinct orders we shall now mention.

Order ANOMODONTIA. Reptiles represented in the Permian and the Trias, with lizard-like bodies and legs adapted for walking. They are believed to be related to the Labyrinthodont Amphibians, and to the ancestors of Mammals. Examples:—*Pariasaurus*, *Galesaurus*, *Dicynodon*.

Order SAUROPTERYGIA. Reptiles represented from the Trias to the Chalk, without exoskeleton, usually with a long neck and a short tail.

DIAGRAM XXIX.

REPTILES.

Head (after Nuhn) shews the fangs and fang-sheaths of a venomous serpent.

Croc. (after Wiedersheim) is a ventral view of a crocodile's skull; *Pmx.* premaxillæ, *M.* maxillæ, *Pl.* palatines, *Pt.* pterygoids, *p. n.* posterior nares; *Q.* quadrate, *B. o.* basi-occipital, *Orb.* the orbit, *Ts.* os transversum, *jg.* jugal, *Qj.* quadrato-jugal.

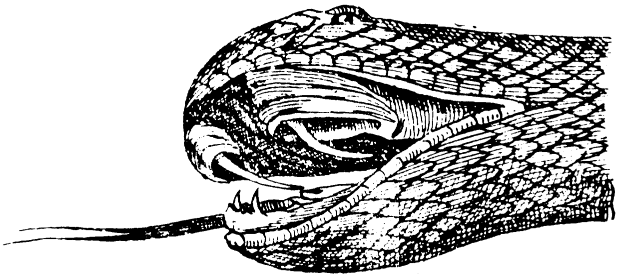
Circ. (after Nuhn) is a diagram of the heart and associated blood-vessels in the tortoise; *s. v. c.* the superior venæ cavæ, *i. v. c.* the inferior vena cava, *r. a.* right auricle, *r. v.* right half of ventricle, *r. p. a.* and *l. p. a.* right and left pulmonary arteries, *p. v.* pulmonary veins, *l. a.* left auricle, *l. v.* left half of ventricle, aortic trunk (*r. a.*) giving origin to right aortic arch (*r. a.*), and to subclavians (*s. cl.*) and carotids (*c.*), *l. a.* left aortic arch from the right ventricle, *d. a.* the dorsal aorta formed from the union of the two aortic arches, *cœl.* the cœliac artery from the left aortic arch.

The figures named *Gird.* (after Gegenbaur) represent the pectoral girdles of lizard (*B.*) beneath, and tortoise (*A.*) above.

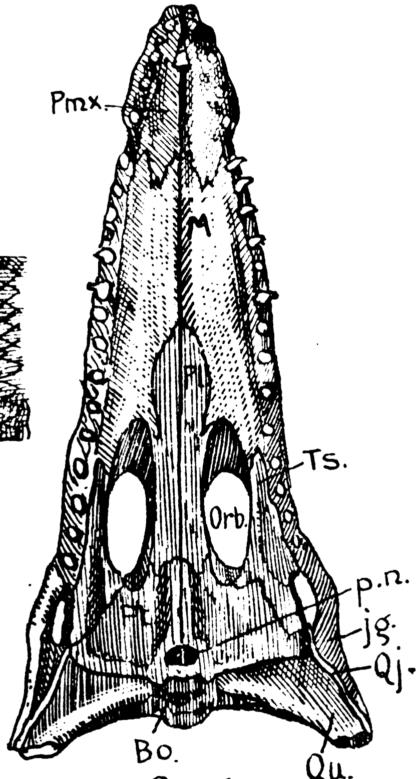
In the pectoral girdle of the lizard are shewn:—*sc.* scapula, *cor.* coracoid, *cl.* clavicle, *i. cl.* inter-clavicle, *st.* sternum.

In the pectoral girdle of the tortoise are shewn:—*sc.* scapula, *cor.* coracoid, *p. co.* "pre-coracoid."

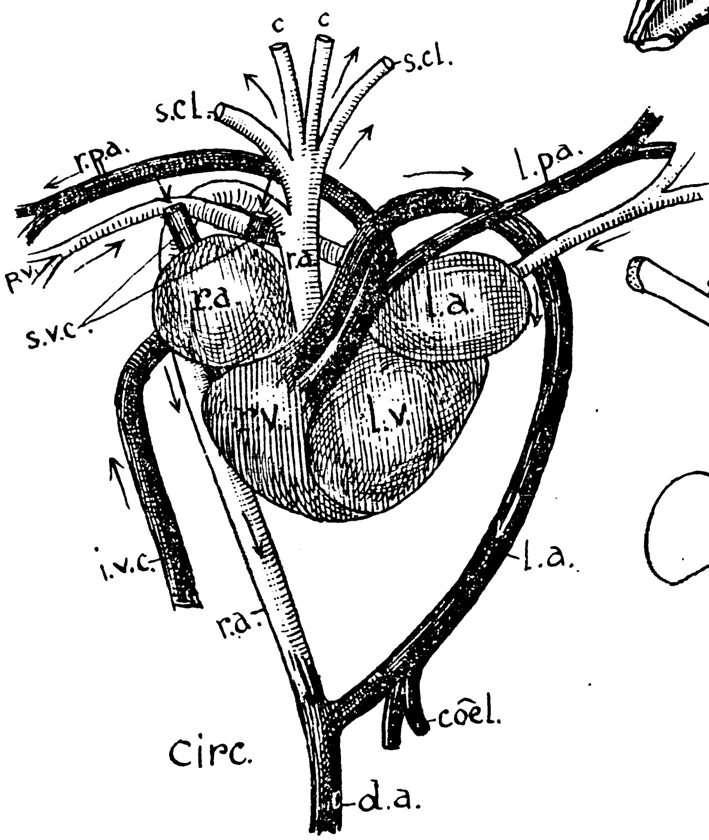
Reptiles.



Head.



Croc.



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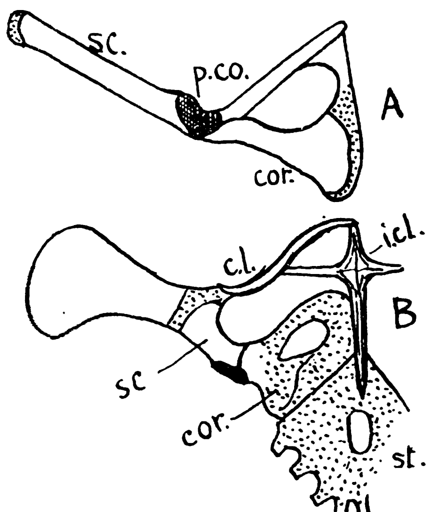


Gird.

They are believed to have affinities with Amphibians, Chelonians, and Rhynchocephalia. Examples:—*Nothosaurus*, *Plesiosaurus*, *Mesosaurus*.

Order ICHTHYOPTERYGIA. Large marine carnivorous Reptiles, represented from the Trias to the Chalk, with long cetacean-like body, without exoskeleton, with limbs adapted as paddles. They seem to have some affinities with Labyrinthodonts and with *Sphenodon*. Some measured thirty to forty feet in length. Examples:—*Ichthyosaurus* (with some viviparous species), *Mixosaurus*, *Opthalmosaurus*.

Order DINOSAURIA. Large terrestrial Reptiles, ranging from the Trias to the Chalk, presenting distinct affinities with Crocodilians and with Birds. Examples:—*Camptosaurus*, a type of those which have the shaft of the pubis directed backward as in Birds; *Compsognathus*, undoubtedly hopped on its hind-legs, after the manner of a bird; *Iguanodon*, another which walked on its hind-legs, and had hollow limb bones; *Stegosaurus*; *Megalosaurus*, a type of those in which the pubes sloped forward; *Ceratosaurus*, one of the horned Reptiles; *Atlantosaurus*. Some of the Dinosaurs were gigantic, thus Marsh estimates the total length of *Brontosaurus* at upwards of fifty feet, and its weight at more than twenty tons,—while the still larger *Atlantosaurus immanis* had a femur measuring slightly over six feet. Many had small heads and brains. Some were amphibious, and it is likely that many of them browsed on succulent plants.

Order ORNITHOSAURIA. Flying Reptiles, represented from the lower Jurassic to the Upper Chalk, exhibiting many affinities with Carinate Birds, but still distinctly Reptilian. An expansion of the skin seems to have been stretched on the much elongated outermost finger, and to have extended backward to the hind-legs and the tail. Some are said to have had an expanse of wing of nearly twenty-five feet; others were no larger than crows. Examples:—*Pterodactylus*, *Rhamphorhynchus*; *Pteranodon* and some others were toothless.

Pedigree of Reptiles.—We know that some of the extinct Saurians were generalised types, presenting affinities not only with several of the extinct orders, but also with several of the living types. It is likely that subsequent research will unify the class of Reptiles. We also know that some of the extinct forms have affinities with Amphibians, with Birds, and with Mammals. Although we cannot with certainty regard any of the extinct types of Reptiles as directly ancestral to either Birds or Mammals, it is likely that the ancestors of these two highest classes were among the ancient Reptiles.

Development of Reptiles.

The development of Reptiles has not been much investigated; in most ways the early stages agree with those observed in Birds. As the latter will be discussed in the next chapter, only a few notes are here necessary.

The ova contain much yolk, at one pole of which there is a small quantity of formative protoplasm surrounding the germinal vesicle. Formation of polar globules has not been observed. The segmentation is necessarily meroblastic and discoidal, as in Birds.

The segmented area or blastoderm, originally at one pole, gradually grows round the yolk. The central region of the dorsal blastoderm is separated from the yolk by a shallow space filled with fluid, and is clearer than the rest of the blastoderm. In this central region or area pellucida, the germinal layers and subsequently the parts of the embryo are established, while the rest of the blastoderm—the area opaca—simply forms a sac around the yolk. One of the first signs of development is the appearance of a thickened band of cells extending forward in the middle line from the posterior margin of the area pellucida. This band is called the primitive streak, and seems to represent a fusion of the two edges of the blastoderm behind the future embryonic region. The embryo develops in front of the primitive streak, and one of the first signs of its development is the formation of a primitive or medullary groove in a line with the primitive streak. As development proceeds, folds appear around the embryo, constricting it off from the subjacent yolk or yolk-sac.

Fœtal Membranes.—It is with Reptiles that the series of higher Vertebrates or Amniota begins. It is here that the fœtal membranes known as amnion and allantois are first formed. Let us consider their development.

(*a*) *The Amnion.*—At an early stage in development, the head end of the embryo seems to sink into the subjacent yolk. A semilunar fold of the blastoderm, including epiblast and mesoblast, rises up in front. Similar folds appear laterally. All the folds increase in size, arch upwards, and unite above, forming a dome over the embryo. Each of these folds is double; the inner limbs unite to form "the true amnion;" the outer limbs unite to form "the false amnion," "serous membrane," or sub-zonal membrane. The cavity bounded by the true amnion contains an amniotic fluid bathing the outer surface of the embryo; the cavity between the true and the false amnion is lined by mesoblast, and is really an extension of the body-cavity of the embryo. The amniotic folds extend not only over the embryo, but ventrally around the yolk-sac which they completely invest.

(*b*) *The Allantois.*—While the amnion is being formed, a sac grows out from the hind end of the embryonic gut. This is the allantois, lined internally by hypoblast, externally by mesoblast. It rapidly insinuates itself between the two limbs of the amnion, eventually surrounding both embryo and yolk-sac.

The amnion is a protective membrane, forming a kind of water-bag around the embryo. It seems to be due in part to the embryo sinking into the yolk-sac by its own weight.

The allantoic sac is vascular, and has respiratory and perhaps also some yolk-absorbing functions. It seems to be homologous with the outgrowth which forms the cloacal bladder of Amphibians; it is often called "a precociously developed urinary bladder."

Before the amnion is developed, the heavy head end of the embryo, has already sunk into a depression (in Lizards, Chelonians, Birds (?)

and Mammals), and is surrounded by a modification of the head fold termed the pro-amnion. This does not include any mesoblast, and is afterwards replaced by the amnion.

Some Peculiarities in Chelonians.—Mitsukuri has recently investigated the development of the fœtal membranes in Chelonians (*Clemmys* and *Trionyx*), and has demonstrated some interesting peculiarities.

The amnion has at first the nature of a pro-amnion, consisting in the region of the sunken head of epiblast and hypoblast, and in the dorsal region of epiblast alone, being as yet non-mesoblastic. The cœlomic cavities of the amniotic folds are not united with each other dorsally in the usual fashion; a connection between the "true amnion" and the "serous membrane" separates the cavities to the very end of the development. The anterior and lateral amniotic folds are continued backward beyond the posterior end of the embryo, as a long tube connecting the amniotic sac with the exterior. This tube perhaps conveys nutritive matter from the albumen into the amniotic cavity. In *Clemmys*, a process from the fœtal membranes projects into a small persistent mass of albumen, and seems to absorb nutritive particles.

Hints of a Placenta before Mammals.—As will be explained afterwards, the placenta, which characterises most Mammals, is an organic connection between mother and unborn young. Its embryonic part is chiefly formed from a union of the serous or sub-zonal membrane and the allantois, but in some cases the yolk-sac and the sub-zonal membrane form a provisional placenta. The placenta establishes a vital union between the embryo and the mother.

Now it is interesting to notice, that there are some hints of placental connection in animals which are much lower than Mammals. In *Mustelus* and a few other Elasmobranch fishes, there is a connection between the yolk-sac and the wall of the uterus; in the Teleostean *Anableps*, the yolk-sac has small absorbing outgrowths or villi; in *Trachydosaurus* and *Cyclodus* among Lizards, the vascular yolk-sac is separated from the wall of the uterus "only by the porous and friable rudiment of the egg-shell;" in *Clemmys* among Chelonians, there is, as above described, an absorbing protrusion of the fœtal membranes. In Birds also small villi of the yolk-sac absorb yolk, and others on the allantois absorb albumen. (See A. C. Haddon's *Embryology.*)

CHAPTER XXIV.

BIRDS.

Class AVES.

BIRDS share with Mammals the rank of the highest Vertebrates. Their muscles and skeleton, heart and lungs—indeed, most of their structural arrangements—are not less differentiated than those of Mammals. Their body temperature, exceeding that of all other animals, is an index to their intense activity. It is only because we recognise in Mammals a higher degree of brain development, and a close organic connection between mother and offspring, that we venture to place them above Birds. It is more important to recognise that these two classes represent markedly divergent lines of progress. Before we discuss the structure of Birds, let us consider some of the characteristics of their life.

The Life of Birds.

Life having begun in the waters, slowly gained possession of the dry land and then of the air. Insects among the lower animals, and Birds among the higher, are pre-eminently the creatures of the air; intensely vivacious, typically beautiful in form and colour, dainty and delightful in their ways.

In the Birds we observe a marked increase of emotional life, so that their affection for their mates, their care of their young, the joyousness of their life, often bursting forth in song, have become proverbial among us. With their power of flight they are emblems of freedom.

Flight of Birds.—Most birds use their wings in flight. The feather-covered arms and fingers, the very large breast muscles which raise and depress the wings, the breast-

bone keel to which these muscles are attached, the lightening of the body by means of balloon-like air-sacs and smaller air-spaces, the boat-like shape of the body, and some other structural peculiarities, are more or less directly associated with the power of flight. Let us consider these peculiarities.

The feathers used in flight are borne by the arm and by the fingers. In those which are most important, the vane of the feather is large, and its lateral barbs are firmly bound together by little barbules, so that the vane, though very light, is able to beat the air as an oar strikes the water. But the base of each feather is embedded in the skin in such a way that it can be independently moved by muscles, and, according to Marey, each feather has in flight a motion of its own. The feathers come close together during the down-stroke, they are separated and placed on edge during the elevation of the wing.

The most external muscle of the breast depresses the wing, making the stroke which carries the bird forward and keeps it from sinking. As it has most work to do, it is by far the largest muscle. Internal to it lies a second muscle, which raises the wing for the next stroke, and there are other smaller muscles of less importance. When we consider the number of strokes which a bird may make in a minute, or the distance that it can travel on the strength of one stroke, we realise how powerful these wing muscles are.

The keel of the breast-bone serves as a base of insertion for the two important muscles, and its size bears some proportion to the strength of flight. It is naturally absent in the running-birds, such as the ostrich and the emu; it has degenerated in the New Zealand parrot *Stringops*, which has ceased to fly and has taken to burrowing. In connection with the skeleton, we should also notice that the well-developed collar-bones or clavicles (which are often joined in front to the breast-bone), and the strong coracoids which articulate with the breast-bone, are admirably adapted to resist the inward pressure caused by the stroke of the wing.

As to the air-sacs and air-spaces, we must avoid falling into the old error of supposing, that the bird is a sort of balloon which can hardly help rising. For there is no doubt that even the lightest of birds has to keep itself from

falling by frequent effort, while some of the heaviest birds fly most swiftly. The bird is not comparable to a balloon, but to a flying machine; "it has to be, not a buoyant cork, but a buoyant bullet." On the other hand, there is no doubt that the hollowness of the bones makes it possible to combine much strength with little weight, while the heated air which fills the air-sacs around the lungs must make it easier for the bird to raise itself from the ground.

The form of the bird is also important, for the motion of a body through the air, and the measure of support which the air gives to it, vary greatly according to the form of the body. Just as the speed of a boat varies with its shape, so is it with the flight of a bird. Buffon noted that eagles disappeared from sight in about three minutes, and it seems that a common rate of flight is about fifty feet per second.

Ruskin has compared the flight of a bird to the sailing of a boat. "In a boat, the air strikes the sail; in a bird, the sail strikes the air; in a boat, the force is lateral, and in a bird downwards; and it has its sail on both sides." But, as he says, the sail of a boat serves only to carry it onwards, while wings have not only to waft the bird onwards, but to keep it up. To carry the weight of the bird the wings strike vertically, to carry the bird onwards they strike obliquely; sometimes the direction of the stroke is more vertical, and then the bird soars or hovers; sometimes it is more oblique, and then the bird speeds onwards; usually both directions are combined. The raising of the wing after each stroke is relatively effortless, the resistance to be overcome being very slight. In steering, the feathers of the tail often bear to the wings a relation comparable to that between rudder and sail.

There are many different kinds of flying. The humming-birds flutter beside the flowers with rapidly vibrating wings; the kestrel hovers "in the face of a stiff gale or in a perfect calm;" the albatross sails in the wind as a kite does, "its own weight answering the purpose of the string." There is no motion more marvellous or more beautiful than the flight of a bird. It is harmonious with the bird's true nature. For there is more than poetical insight in Ruskin's description:—"The bird is little more than a drift of the air brought into form by plumes; the air is in all its quills,

it breathes through its whole frame and flesh, and glows with air in its flying; like a blown flame it rests upon the air, subdues it, surpasses it, outraces it; *is* the air, conscious of itself, conquering itself, ruling itself."

The Song of Birds.—Singing is a natural expression of emotional wealth. The song rises in the bird, Richard Jefferies said, as naturally as the sap in the bough. It is richest at the climax of emotion in the breeding season, and is always best and often solely developed in the males. But song in any excellence is the gift of comparatively few birds, though nearly all have a voice of some sort, often so characteristic that the species may be recognised by its call alone. The twittering of swallows, the cawing of rooks, the melancholy voice of the sea-mew, the lapwing's prayerful cry, the weird call of the curlew, are familiar to most of us. A few birds, notably the parrot and the jackdaw, can be taught to pronounce articulate words; but the power of imitation is widespread among birds, the case of the canary learning the song of the nightingale being a well-known instance. This power of imitation has some importance in relation to the general theory of instinct, for the song of all birds is probably in great part imitative, though to a certain extent the musical talent is really inherited. Young birds taken away from their nests when very young, so that they have hardly heard the voices of their kind, will sing the characteristic song of the species, but do so imperfectly.

The vocal organ of Birds is not situated in the larynx as it is in Mammals, but in the syrinx—a song-box at the base of the windpipe. In this syrinx there are vocal membranes or folds of skin; their vibration as the air passes over them causes sound; the note varies with the muscular tension of the folds, with the muscular state of the complex associated parts, and with the column of air in the windpipe.

Courtship.—Birds usually pair in the springtime, but there are many exceptions. Some, such as the eagles, live alone except at the pairing time; others, notably the doves, always live together in pairs, and are thus remarkable for the constancy and refinement of their affections; many, such as rooks, parrots, and cranes, are sociable gregarious birds. A few, like the fowls, are polygamous; the cuckoo is polyandrous.

In most cases, however, birds pair, and the mates are true to one another for a season. The pairing is often preceded by a courtship in which the more decorative, more vocal males win their desired mates, being to some extent chosen by them. Darwin attributed the captivating characteristics of the males, well seen in peacocks and birds of paradise, or as regards musical powers in most of our own British songsters, to the sexual selection exercised by the females; for if the more decorative or the more melodious males always got the preference in courtship, the qualities which contributed to their success would tend to predominate in the race. He believed, moreover, that characteristics of male parents were entailed on male offspring. Wallace regarded the differences between males and females in another way, arguing that natural selection had eliminated the more conspicuous females, for brightness would be disadvantageous during incubation. It seems likely enough that both conclusions are to some extent true, while there is much to be said in favour of a deeper explanation, to which Wallace inclines, that the differences between the sexes are natural and necessary expressions of the constitutional differences involved in maleness and femaleness.

Nests.—After pairing, the work of nest-building is begun. Almost all birds build nests; the well-known habit is a characteristic expression of their parental care. Other creatures, indeed, such as sticklebacks among Fishes, and squirrels among Mammals, besides numerous Insects, build nests, but the habit is most perfectly developed among Birds. As is well known, each species has its own peculiar style of nest, and builds it of special materials. Generally the nest is solitary, hidden in some private nook. The perfection of art which is reached by some birds in the making of their nests is marvellous; they use their bills and their feet, and smooth the inside by twisting round and round. Usually the hen does most of the work, but her mate sometimes helps, both in building the nest and in hatching the young.

The nest is a cradle rather than a house, for its chief use is to secure an approximately constant warmth for the young which are being formed within the eggs, and to afford protection for the helpless fledglings. At the same time, the

nest secures the comfort of the parent bird during the days and nights of brooding.

The variety of nests may be illustrated by mentioning the burrowed nests of sand-martins and kingfishers, the ground-nests of game-birds and gulls, the mud-nests of house-swallow and flamingo, the holes which the woodpecker fashions in the tree stem, the platforms built by doves and eagles, storks and cranes, the basket-nests of most singing-birds, the structures delicately woven by the goldfinch, bullfinch, and humming-birds, the sewed nest of the tailor-bird, the mossy nests of the wrens, the edible nest of the *Collocalia*, which is chiefly composed of the secretion of the salivary glands.

The Eggs of Birds.—When the nest is finished, the eggs are ready to be laid. After they are laid, the patience of brooding begins. With the great care that Birds take of their young we may associate the comparatively small number of the eggs; but it is more accurate to recognise that, as animals become more highly evolved, the number of offspring decreases. Yet it must be remembered that inductions of this kind are only generally true, for subsidiary conditions often bring about the apparent contradiction of a general truth. Thus we are not justified in saying that the *Apteryx* which lays one egg is a more highly differentiated bird than the ostrich which lays many.

The size of the egg usually bears some relation to the size of the bird. Of European birds, the swans have the largest eggs, the golden-crested wren the smallest. It is said that the egg of the extinct *Moa* sometimes measured nine inches in breadth and twelve inches in length: while that of the extinct *Æpyornis* held over two gallons, some six times as much as an ostrich's egg, or a hundred and fifty times as much as a fowl's. Yet the size of the egg is only generally proportional to that of the bird; for while the cuckoo is much larger than the lark, the eggs of the two have about the same size; and while the guillemot and the raven are almost of equal size, the eggs of the former are in volume about ten times larger than those of the latter. Hewitson has noted that the eggs of birds, whose young are rapidly hatched and soon leave the nest, are large; Professor Newton remarks that "the number of eggs to be covered at

one time seems also to have some relation to their size," while from what one notices in the poultry-yard, and from a comparison of the habits of different birds, it seems probable that a highly nutritive, sluggish bird, will have larger eggs than a bird of more active habit and sparser diet.

The shell of the egg is often very beautifully coloured; there is a predominant tint upon which are spots, streaks, and blotches of varied colour and disposition, so that the egg is almost always characteristic of the species. The colouring matter consists of pigments related to those of the blood and bile, and is deposited while the shell is being formed in the lower part of the oviduct. As the egg may move before the pigments are fixed, blotches and markings naturally result. But the most interesting fact in regard to the colouring of the egg-shells, is that the tints are often protectively harmonious with those of the surroundings. Thus, eggs laid almost on the ground are often brownish like the soil, those laid in rocky places by the sea often look very like stones, while conspicuous eggs are usually found in covered nests. The colouring changes a little according to the constitution of the bird, and Professor Newton inclines to the opinion that eggs with the richest colours are laid by birds at their prime. M'Aldowie maintains that the colouring varies according to the amount of light to which the eggs are exposed, and Lucas believes that the colouring of the surroundings influences the mother-bird, and indirectly affects the colouring of the egg-shells. The facts require to be more precisely known before any certain conclusion can be reached.

The state of the newly hatched young is very various. Some are born naked, blind, and helpless, and have to be carefully fed by their parents until they are fully fledged. This is true of the thrush and of many other song-birds. Others are born covered with down but still helpless; while a few, like the chicks, are able to run about and feed themselves a few minutes after they leave the egg. Those which require to be fed and brooded over are sometimes called Altrices or Insessores, while those which are at once active and able to feed themselves are called Præcoces or Autophagæ.

Moulting.—Every year Birds lose their old feathers. This moulting generally takes place after the fatigue of the breeding season, but in the case of the swallows and the diurnal birds of prey and some others the moult is in mid-winter. The process is comparable to the casting of scales in Reptiles, and to the shedding of hair in Mammals. Feathers are so easily injured that the advantage of the annual renewal is evident, especially when it takes place just before the time at which it may be necessary to set forth on a long migratory flight.

In moulting, the feathers fall out and are replaced gradually, but sometimes they are shed so rapidly that the bird is left very bare, thus moulting ducks are unable to fly. There are many birds that moult, more or less completely, more than once a year; thus the garden warbler sheds its feathers twice. The males of many bright birds assume special decorations after a partial moult, which occurs before the time of pairing. Most remarkable is the case of the ptarmigan, which changes its dress three times in the year; after the breeding season is over the plumage becomes grey; as the winter sets in it grows white, and suited to the surrounding snow; in the spring, the season of courtship, the wedding-robes are put on.

Diet.—The food of Birds varies greatly, not only in different kinds, but also at different seasons. Many are herbivorous, feeding on the soft green parts of plants, and in these birds the intestine is long. Some confine themselves to grain, and these have large crops and strong grinding gizzards, while those which combine cereals and insects have in most cases no crop. A few sip honey, and may even help in the cross-fertilisation of flowers; those that feed on fruits play an important part in the dissemination of seeds; those that devour insects are of great service to man. In fruit-eating and insectivorous birds the crop is usually small, and the gizzard only slightly muscular. But many birds feed on worms, molluscs, fishes, and small mammals; in these the glandular part of the stomach is more developed than the muscular part. It has been shown that the nature of the stomach in the Shetland Gull changes twice a year, as the bird changes a summer diet of grain and seeds for a winter diet of fish, and *vice versa*. In the case of

canaries, bullfinches, and parrots, it has been noted that the food influences the colouring of the plumage.

Migration.—The migrations of birds have been observed and speculated upon from the earliest times, and in many countries, but we are still far from possessing complete knowledge of the matter. The arrival in spring and departure in autumn of the swallow is a fact familiar to every one; but so far from this habit being the exceptional one it was commonly thought to be, it seems that there are few species of birds, save those of the tropics, that do not change their habitat to some extent in accordance with the varying seasons. One of the most remarkable facts about the arrival and departure of birds in any district is the regularity with which it occurs; thus the Red Indian names the months after the birds whose arrival is peculiar to the time; while in this country many sea-fowls are credited with punctuality to the day, regardless of weather. The wandering birds of any country where migration has been observed, may be divided into three classes—(1) those that arrive in spring, remain during the summer to breed, and depart in autumn, as the swallow and the nightingale do in this country; (2) others that arrive in autumn, stay through the winter, and fly away in the spring, for example, the fieldfare and the redwing; (3) some, like the sandpipers, which are only known for a short time twice a year, in the spring and autumn, being "birds of passage." These birds are not subject to different influences; they illustrate different phases of migration. Some have come from the north, driven southwards by approaching winter, and find our climate warm enough for them, these are the winter visitors; others come from the south as the weather becomes too warm for them, these are the summer visitors; while the birds of passage are those that pass through the country in the course of a longer migration. All birds nest in the colder countries of their visitings.

As migration is associated with the seasons, we are led to suspect that its cause lies in the change of weather. Out of the tropics all creatures have to adapt themselves to the changing seasons. Alterations of climate may have a direct or an indirect effect. Thus the direct effect of cold upon some animals is such that they are killed; most insects

suffer this fate; others it puts to sleep, they "hibernate;" others escape from the unfavourable conditions by wandering away to warmer lands. The indirect effect is through the lessening of the food supplies; this is probably in most cases the most potent cause of migration. It is natural that birds, gifted above most creatures with powers of long and rapid locomotion, should be the most noted travellers.

As already stated nearly all birds migrate to some extent, but the length of the journey is very various. Some birds of tropical countries are said to move from the hills to the valleys and back again; those of regions of more variable climate may perform flights of hundreds of miles, at times even over the sea. There are fairly well marked paths of migration, such as from Russia, down the west coast of Norway, across the North Sea to Britain; another from Spitzbergen along the same course, but continued, through France and Spain, to the west coast of Africa, and so on. River valleys form minor routes.

The thing that is so difficult to understand about these long migrations is, how do the birds find their way, not only over land, but over the trackless sea, and how do they return with such precision to the same spots year after year? Perhaps in the case of those birds that fly in flocks the older ones, who have performed the journey before, lead the others; even then the thing is wonderful. But many birds do not fly in flocks; and further, migrations are often performed in the darkness of night.

Wallace's theory of the origin of the habit and its perfecting by aid of natural selection is now widely accepted. He supposes in past times a more equable climate than at present; as the seasons become more distinct, the birds had to fly further and further; those that did not fly at the right time and in the right direction would, as the necessity for migration became more imperative, become extinct, and so the habit might become fixed as an instinct.

Intelligence and Emotions.—As birds usually live a full life, with variety of function and stimulating environment, it is natural that their sense-organs and nervous system should be highly developed, that they should be clever. Moreover, their parental care and their courtships, while of course presupposing emotion, must have tended to foster it. While

much of the cleverness of a bird may be traced to instinct or inherited habit, there is no doubt that they are quick to learn from experience, that they have good memories, and that they can adapt new means to new ends. Some are fond of music and quick to imitate tunes. The bower-bird is an outstanding rather than an exceptional illustration of their liking for beautiful things.

General Survey of the Class.

Order 3. Flying Birds—Carinatæ—the great majority of living birds.

Order 2. Running Birds — Ratitæ — only a few, the Ostriches (*Struthio* and *Rhea*), the Emu (*Dromæus*), the Cassowary (*Casuarius*), the Kiwi (*Apteryx*), and some extinct forms.

Order 1. Saururæ. Ancient extinct birds, such as *Archæopteryx*.

General Characters of Birds.

The fore-limbs are generally modified as wings capable of flight; the neck is long, the tail short.

The epidermic exoskeleton is represented by feathers, sometimes also by a few scales, but there are never any scutes.

The only skin-gland is an oil-gland or preen-gland at the root of the tail.

The pectoral muscles used in flight are generally greatly developed; in many there is a muscular gizzard; the diaphragm is not more than incipient.

In the brain, the predominance of cerebrum and cerebellum has resulted in displacing the optic lobes to the sides.

The nostrils are often overhung by a sensitive cere; there is no external ear, and the connection between tympanum and inner ear is by means of a columella; the eye-ball is strengthened by sclerotic ossicles, there is a well-developed third eye-lid and an internal nutritive pecten.

There are no epiphyses in connection with the bones,

which are light and airy. The curvature of the vertebral centra is peculiar. The cervical vertebræ have little ribs. A large number of vertebræ fuse with the two or three true sacrals. The terminal vertebræ of the tail are fused in a ploughshare bone.

The bones of the skull fuse, the sutures being quite obliterated. Only the lower jaw, the quadrate, the columella, and hyoid, are always movable, but there may be a joint in the beak at the end of the premaxillæ. There is but one condyle. A membrane bone called the basi-temporal covers the basi-sphenoid. There is an inter-orbital septum formed from presphenoid and mesethmoid. The otic bones fuse with adjacent bones, and with one another about the same time. There are no teeth. The jaws are covered by horny sheaths. The premaxillæ are large and form most of the beak. The lower jaw consists on each side of five membrane bones and a cartilage bone—the articular—which works on the quadrate.

There is a well-developed sternum, generally with a keel to which the pectoral muscles are attached. The strong coracoids reach and articulate with the sternum. In flying birds, the clavicles are well developed, and are usually connected by an interclavicle, which is often fused to the top of the breast-bone. The fore-limb has not more than three digits, the three metacarpals are fused, and there are only two separate carpals, the others fusing with the metacarpals.

The dorsal ilia of the pelvis are fused to the complex sacrum; the acetabulum is not thoroughly ossified; the pubes (or post-pubic processes) are directed backwards parallel to the ischia. There is no pubic symphysis except in the African ostrich (*Struthio*), and no ischiac symphysis except in the American ostrich (*Rhea*). In the hind-limb, the fibula is incomplete and united to the side of the tibia; there are no free tarsal bones, half of them being united to the distal end of the tibia (which is therefore called a tibio-tarsus), the others being united to the proximal end of three united metatarsals (which thus form a tarso-metatarsus); the maximum number of toes is four, but if there be a fourth, its metatarsal is free from the other three.

In regard to the alimentary system, the absence of teeth, the frequent occurrence of a crop and a gizzard, the frequent

DIAGRAM XXX.

Birds.

The figure named *Brain* shows the cerebral hemispheres (*cer. h.*) with small olfactory lobes (*olf.*), the cerebellum (*cerebell.*), the pineal body (*p. b.*), the optic lobes (*opt.*), the medulla oblongata (*m. o.*).

Skull (after W. K. Parker) shows the position of the following bones:—parietal (*p.*), frontal (*f.*), post-frontal process (*p. f.*), mesethmoid (*me.*), lachrymal (*l.*), premaxilla (*px.*), maxilla (*mx.*), vomer (*v.*), pterygoid (*pt.*), quadrate (*q.*), squamosal (*sq.*), jugal (*j.*) quadrato-jugal (*q. j.*), dentary (*d.*), angular (*a*), articular (*ar.*).

Arm (after W. K. Parker) shows humerus (*h.*), ulna (*u*), radius (*r.*), the ulnar carpal (*u'*), the radial carpal (*r'*), the three united metacarpal (marked *II.* and *III.*), the phalanx of the thumb (marked *I.*), the phalanges of the other two digits.

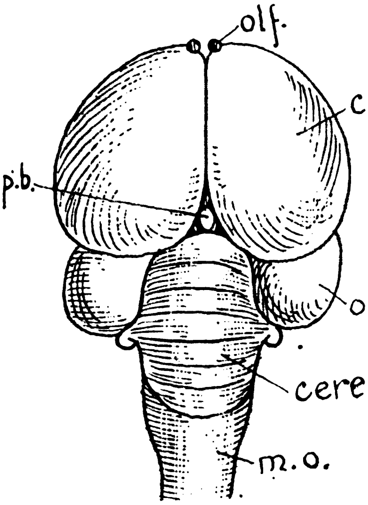
The *Feather-germ* (from Wiedersheim) shows the dermis (*Derm.*), the feather-follicle (*F.*), the stratum Malpighii (*s. m.*) and the stratum corneum (*s. c.*) of the epidermis.

Blast I. (after Balfour) shows in section the segmented area or blastoderm (*bl.*) on the top of the yolk (*y.*), with the segmentation cavity (*s. c.*) between them.

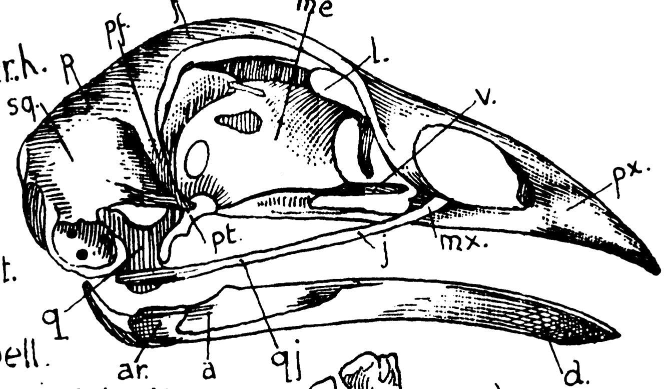
Blast II. (after Balfour) is a surface view of the blastoderm, *p. s.* the primitive streak, *m. g.* the medullary groove, *h. f.* the incipient head-fold, *am. f.* the incipient amnion-fold.

Egg (after Allen Thomson) shows a diagrammatic section of the egg, the shell (*s.*), the outer shell-membrane (*s. m.*), the inner shell-membrane (*i. s. m.*), the air-chamber (*a. ch.*), the white of egg (*wh.*), the chalazæ (*ch.*), the vitelline membrane (*v. m.*), the yolk (*y.*) with white yolk in layers among the (dark) yellow yolk, and forming also a central mass, the position of the incipient blastoderm (*bl.*).

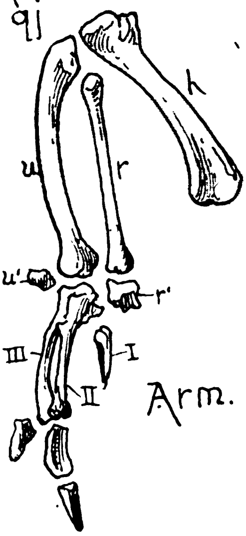
Birds.



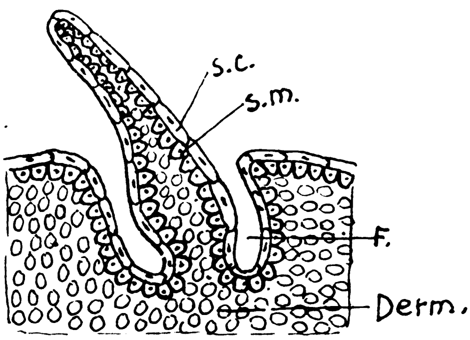
Brain.



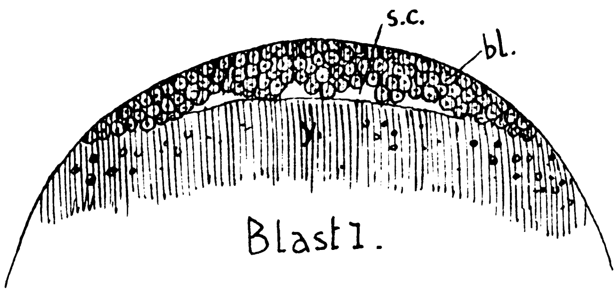
Skull.



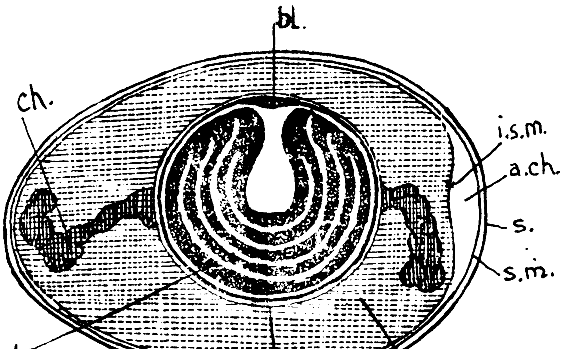
Arm.



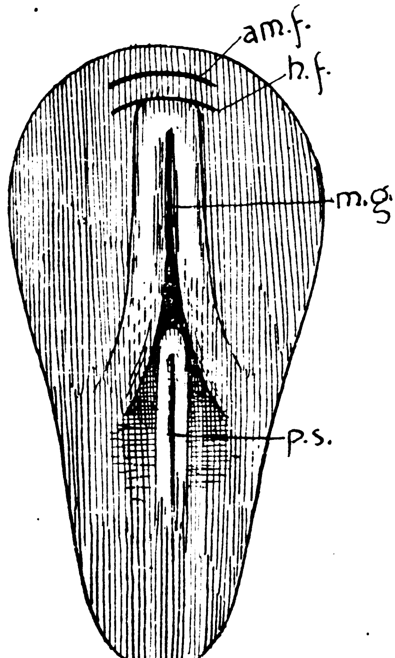
Feather-germ.



Blast 1.



Egg.



Blast 2.

shortness of the large intestine, the presence of a cloaca, may be noted.

The heart is four-chambered; the single aortic arch curves to the right side; only the pulmonary artery rises from the right ventricle; the valves between the right auricle and the right ventricle are in part themselves muscular; the red blood-corpuscles are oval and nucleated; the temperature of the body is from 2°–14° F. higher than that of Mammals, and much higher than that of the cold-blooded Reptiles.

The lungs are fixed to the dorsal wall of the thorax; the bronchial tubes expand in irregular branches in the lungs; the ends of some of these branches are continued into air-sacs surrounding the lungs; these air-sacs are in communication with air-spaces in the bones. The trachea is supported by bony rings, and has a larynx at its upper end, and a syrinx or song-box at the origin of the bronchi.

The kidneys are three-lobed, and lie embedded in the pelvis; the ureters open into the cloaca; there is no bladder; the urine is semi-solid, and consists chiefly of urates.

The testes lie beside the kidneys; the vasa deferentia run beside the ureters and open into the middle region of the cloaca. The right ovary atrophies, the right oviduct is rudimentary.

The eggs have much yolk and a hard calcareous shell. The segmentation is meroblastic and discoidal. The allantois is chiefly respiratory, though it may also help in absorbing the nutritive substance of the egg.

The Pigeon (*Columba*) considered as a type of Birds.

The varieties of domesticated pigeon with which we are familiar, are all descended from the rock-dove, *Columba livia*, and afford very vivid illustrations of variation, and of the results of artificial selection. The power of rapid flight, the diet of seeds, the affection between mates and between the parents and their young are well known.

Form and External Characters.—The form, well suited for rapid flight, ceases to be graceful when stripped of its feathers. The cere overarching the nostrils, the third eyelid hidden in front of the eyeball, the external opening of the ear almost concealed by the feathers, the preen-gland on the

dorsal surface at the root of the tail, the cloacal aperture, are external features easily demonstrated.

Feathers.—The feathers most important in flight are the remiges of the wing, divided into primaries borne by the fingers, and secondaries by the ulna. The feathers of the tail help to guide the flight, and are called rectrices. A distinct tuft of feathers borne by the thumb is called the bastard wing. Covering the bases of the large feathers are the coverts,—wing-coverts and tail-coverts,—while other small feathers give shape to the whole body. In the pigeon there are no true down feathers or plumules, but among the ordinary contour feathers or pennæ, there are little hair-like feathers called filoplumes, which bear only a few terminal barbs.

Any one of the large feathers consists of an axis or scapus divided into a lower hollow portion—the calamus or quill, and an upper solid portion—the rachis, which forms the centre of the vane. This vane consists of parallel rows of lateral barbs, linked to one another by barbules, which may be joined to one another by microscopic hooklets. The quill is fixed in a pit or follicle of the skin with which muscle fibres are connected. At the base of the quill there is a little hole—the inferior umbilicus—through which a nutritive papilla of dermis is continued into the growing feather. At the base of the vane there is a little chink—the superior umbilicus—but this has no importance. Close to this region, however, in many birds a tuft or branch arises which is called the aftershaft. In the Emu and Cassowary, the aftershaft is so long that each feather seems double.

A feather grows from a papilla of skin, but the whole of the feather is really formed from the cornification of one layer of the epidermis. The papillæ rarely occur diffusely on the skin, but are usually disposed along definite lines or feather-tracts, where the skin has been wrinkled. Each papilla consists externally of epidermis and internally of dermis, and becomes surrounded by a depression or moat, which deepens to form the feather-follicle or the sac in which the base of the quill is sunk. But the epidermis has two layers—(*a*) an outer stratum corneum, which in the developing feather forms merely a protective external sheath, and (*b*) an inner stratum Malpighii, which be-

comes cornified, and forms the whole feather. The process by which this cylinder of cells becomes horny is remarkable; in the upper part ridges are formed which separate from one another as a set of barbs, the lower part remains intact as the quill. When we pull the horny sheath off a young feather, we disclose a set of barbs lying almost parallel with one another, but slightly divergent. The central one predominates as the rachis, and its neighbours gradually become its lateral barbs. As for the external sheath, it falls off, while the core of dermis is wholly nutritive, and disappears as the feather ceases to grow.

On the toes and on the base of the legs little epidermic scales occur. The toes are clawed, and in some birds the same is true of the thumb and first finger. Only in the embryos of the hoatzin (*Opisthocomus*) and of the ostriches (*Struthio* and *Rhea*) is the second finger clawed. The beak is covered by a horny sheath, which is annually moulted in the puffin. The dermis is very thin and vascular, and is rich in tactile nerve endings or Paccinian corpuscles, which are especially abundant in the cere. The only skin-gland —the preen-gland—secretes an oily fluid, with which the bird anoints its feathers. It is absent in the ostrich, emu, cassowary, and kiwi, and in a few Carinate birds.

Muscular System.—The largest pectoral muscle arises from the sternum and its keel, and from the clavicle; it is inserted on the humerus and depresses the wing. It is called the pectoralis major. The smaller but longer muscle —the pectoralis minor—exposed when the large one is reflected, elevates the wing. It arises from the keel and sides of the sternum, and is continued over the shoulder to its insertion on the dorsal surface of the humerus. Arising chiefly from the coracoid, but in part from the sternum, and inserted on the humerus is a small coraco-brachialis which helps a little in raising the wing. There are several yet smaller muscles.

Interesting also is the mechanism of perching. When the bird sits on its perch, the toes clasp this tightly. The flexor tendons of the toes are continued upwards in flexor muscles over the metatarsal joint to the tibia, and are flexed automatically when the leg is bent during perching. Furthermore, an ambiens muscle, inserted on the front of the pubis,

is continued down the anterior side of the femur, bends round the knee to the opposite side of the tibia, and is inferiorly connected by tendons with the flexors of the digits. When the leg is bent in sitting this muscle is stretched, and the digits clasp the branch. Thus the bird when asleep does not fall off its perch.

In connection with the muscular system, we may also notice that the walls of the gizzard consist of thick muscles radiating around tendinous discs. Two small sterno-tracheal muscles ascend from the sternum to the trachea, and move the latter. Of importance are the complex muscles associated with the song-box.

Skeleton.—In Birds there is a marked tendency to fusion of bones, as seen in the skull, vertebral column, pelvis, and limbs. In the pigeon all the bones, except those of the tail, fore-arm, hand, and hind-limb, contain air spaces.

The vertebral column is divided into four regions—cervical, thoracic, sacral, and caudal. In the pigeon the mobile neck consists of fourteen cervical vertebræ with cervical ribs, short except in the last two, which have them well-developed. Of the thoracic vertebræ, namely those whose ribs reach the sternum, the anterior four are fused to one another, while the fifth is fused to the sacral region. The complex sacral region consists of the last thoracic (with ribs), two or three lumbars, three or four sacrals, and six caudals all fused. Lastly, there are about six free caudals, ending in a pygostyle or ploughshare bone, which represents a fusion of several vertebræ.

When we examine one of the cervical vertebræ, we notice that the anterior surface of the centrum has a complex and distinctive curvature. It is concave from side to side, convex from above downwards. Posteriorly the curvatures are of course the reverse. The centra are often shortly described as procœlous and cylindroidal. On the vertebra will also be seen the expanded transverse processes, perforated on each side by an aperture for the vertebral artery, the anterior articular processes or zygapophyses, the posterior articular processes, the large neural arch culminating in a neural spine.

The ribs, borne by five vertebræ, have two heads,—a capitulum articulating with a centrum, a tubercle articulating with a transverse process. The ventral part of the rib

which reaches the sternum is called the sternal rib, and is joined at an angle to the dorsal part of the rib, which articulates with a vertebra. On the posterior surface of each of the first four ribs there is an uncinate process.

The skull has a rounded cranial cavity and a narrow beak, which is mostly composed of the premaxillæ. All the bones are fixed except the quadrate, lower jaw, columella, and hyoid. The surface is polished, the sutures are obliterated very early in life.

The back part of the skull is formed by the basi-occipital, the two ex-occipitals, and the supra-occipital. These bound the foramen magnum through which the spinal cord passes downwards from the brain. The basi-occipital forms most of the single condyle on which the skull rotates.

The top of the skull is formed from the paired parietals, frontals, and nasals, the last being small, and in part superseded by the upward extension of the premaxillæ.

The line of the upper jaw consists of premaxilla, small maxilla, jugal, and quadrato-jugal, the last abutting on the movable quadrate.

Of the membrane-bones on the side of the skull, the lachrymal in front of the orbit, and the squamosal above the quadrate, are the most important.

On the roof of the mouth we find that the basisphenoid, which lies just in front of the basi-occipital, is covered over by a membrane bone—the basi-temporal. In front of this is a sharp "basisphenoidal rostrum," or parasphenoid, also a membrane-bone. Articulating with the quadrate and with the rostrum are the pterygoids, in front of these lie the palatines, between which a part of the vomer may be seen. The bony front of the palate is formed from inward extensions of the premaxillæ and maxillæ. The inter-orbital septum is formed chiefly from the mesethmoid but also from the presphenoid. From the tympanum to the inner ear extends the rod-like columella. The lower jaw originally consists of numerous bones. The hyoid consists of a flat "body," with anterior and posterior "horns."

The pectoral girdle consists of sabre-like scapulæ extending dorsally over the ribs, of stout coracoids sloping ventrally and articulating with the sternum, of the clavicles which are united by the interclavicle to form the merry-thought.

The sternum bears a conspicuous keel, is produced laterally and posteriorly into two xiphoid processes, and bears articular surfaces for the coracoids anteriorly, for the ribs laterally.

The skeleton of the wing includes the stout humerus, the separate radius and ulna (the latter the larger), two free carpals, a carpo-metacarpus of three metacarpals fused to one another and to some carpal elements, and three digits —the thumb with one joint, the first finger with two joints, the second with one.

The pelvic girdle consists of dorsal ilia fused to the complex sacral region, of ischia sloping backwards, and of pubes or post-pubic processes running parallel to the ischia. Besides the disposition of these three elements, the incomplete ossification of the socket or acetabulum, and the absence of ventral symphyses, are noteworthy.

The hind-limb consists of a short stout femur, a tibia to which the proximal tarsals are fused (forming a tibio-tarsus), an incomplete fibula joined to the tibia, three metatarsals fused to one another and to the distal tarsals (forming the tarso-metatarsus), and, finally, three toes, of which the first has two phalanges, the second three, and the third four.

Nervous System.—In contrast to the brain of crocodiles and other Reptiles, the brain of the pigeon and other Birds fills the cranial cavity. The cerebral hemispheres are large and smooth. They meet the cerebellum and throw the solid optic lobes to the sides. The olfactory lobes are very small. Between the cerebral hemispheres and the cerebellum, the pineal body rises to the surface, and a slight posterior separation of the hemispheres will disclose the region of the optic thalami. The cerebellum is ridged transversely and divided into a median and two lateral regions. It will be noted that the curvature of the brain is now well marked in the adult, thus the medulla is quite hidden by and descends almost vertically from the cerebellum.

There are as usual twelve cranial nerves.

In connection with the spinal cord, the brachial plexus of nerves to the fore-arm, and the sacral plexus to the leg, should be noticed. In the lumbar region the halves of the cord diverge for a short distance forming a wide space—the rhomboidal sinus—roofed only by the pia mater. The

cervical part of the sympathetic nervous system is double on each side.

Sense-Organs.—The sense of smell does not seem to be keenly developed in many birds. The nostrils are longitudinal slits overhung by the swollen cere.

The sense of hearing is acute. Externally the ear is marked by an open tube—the external auditory meatus; the aperture of which is surrounded by a regular circlet of feathers. Within the tube beneath the surface lies the drum or tympanum; connecting this with the fenestra ovalis of the inner ear lies the well-developed columella; the tympanic chamber is continued past the ear as the Eustachian tube which unites with that of the opposite side, and opens into the mouth cavity in front of the basi-sphenoid bone. As regards the internal ear, it should be noticed that the cochlea, or curved protuberance of the sacculus, which is incipient in Amphibians, and larger in Reptiles, is yet more marked in Birds.

As to the eye, its protection by an upper, a lower, and a third eyelid or nictitating membrane, is obvious. The front of the sclerotic protrudes in a rounded cone, and is strengthened by a ring of little bones. Into the vitreous humour, a vascular and doubtless nutritive fold called the pecten projects. This is also seen in some Fishes and Reptiles. Birds have remarkable powers of optic accommodation.

The Alimentary System.—The jaws are ensheathed in horn. There are no hints of teeth except in the embryos of some parrots. A narrow tongue lies in the floor of the mouth; it is unimportant in the pigeon, but is thick in parrots, and long in woodpeckers and humming-birds. Associated with the tongue there are numerous glands. Into the mouth there open the posterior nares, and the united Eustachian tubes.

The gullet expands into a thin-walled, slightly bilobed, non-glandular crop, in which are stored the hurriedly swallowed seeds. No great change happens to the food while it remains within the crop, but it is softened a little. At the breeding season the cells lining the crop undergo a strange degeneration, and form "pigeon's milk," which both males and females give to the young birds.

From the crop the food-canal is continued into the

glandular part of the stomach, known as the proventriculus. Here the gastric juice is secreted.

Beneath the proventriculus is the gizzard, in which the food is ground. The walls are very muscular, the fibres radiating from two tendinous discs; the internal surface is lined by a hard cuticle, and within the cavity are small stones which the bird has swallowed. The pyloric opening from the gizzard into the duodenum, is very near the opening from the proventriculus into the gizzard.

In the fold of the long duodenum lies the pancreas with three ducts, and into the same region open two bile-ducts from the liver, which is without a gall-bladder. In most birds the gall-bladder is present. The subtle psychical theory by which the ancients explained its presence in birds of prey and its absence in doves, is untenable.

The small intestine is long; the large intestine is very short, in fact, it is not more than a rectum two inches in length. At the junction of the small and the large intestine, there are two short cæca. In some birds, *e.g.*, the fowl, these are of considerable length.

The cloaca has three divisions, an upper part into which the rectum opens, a median part into which the ureters and the genital ducts open, and a posterior region opening into which from the dorsal surface is a vascular and glandular sac called the bursa Fabricii, which usually disappears during adolescence. The function of this bursa is unknown.

The Vascular System.—The four-chambered heart, the single aortic arch bending over to the right side, the hot blood, are the most important characteristics.

The impure blood having returned by venæ cavæ to the right auricle, passes through the auriculo-ventricular valve which has two muscular flaps into the right ventricle, and is thence driven to the lungs. From the lungs, the purified blood returns to the left auricle, and passes through two membranous valves into the left ventricle. Thence it is driven up the arterial trunk into the carotids, the subclavians, and the dorsal aorta. The bases of the aortic and pulmonary trunks are guarded by three semilunar valves. From the capillaries, the impure blood is collected anteriorly in two superior venæ cavæ, and posteriorly in an inferior vena cava, composed of veins from hind-legs and

kidneys, and receiving as it approaches the heart the hepatic veins from the liver.

The right auricle of the heart is larger than the left; the right ventricle has thin walls, and partly surrounds the more muscular left ventricle.

The arterial system consists of the following vessels:—

(*a*) The arterial trunk, as it rises from the heart, gives off on each side an innominate artery. Each innominate gives off a carotid and a subclavian, and the subclavian immediately divides into a brachial to the arm and a pectoral to the breast muscles.

(*b*) The dorsal aorta, formed by a continuation of the arterial trunk bending round on the right side, gives off cœliac, mesenteric, renal, femoral, sciatic, iliac, and other arteries.

The venous system consists of the following vessels:—

(*a*) Each superior vena cava is formed from the union of jugulars from the head, a brachial from the arm, and a pectoral from the breast.

(*b*) The inferior vena cava is formed from the junction of two iliac veins just in front of the kidneys. Each of these iliacs results from the union of a femoral from the leg, an efferent renal from the kidney, and a renal portal which passes upwards through the kidney. To understand this renal portal, it is convenient to begin at the tail. A short caudal vein divides anteriorly into right and left branches, each of these receives an internal iliac from the sides of the pelvic region; thus a hypogastric or renal portal is formed, which passing upwards through the kidney receives the sciatic, and finally joins with the femoral and the renal.

The hepatic portal system is as usual:—mesenteric veins from the intestine combine in portal veins; the blood filters through the liver; and is collected in hepatic veins, which unite with the anterior end of the inferior vena cava.

The renal portal system is represented by branches which the femoral and sciatic give off to the kidney.

From the transverse vein formed between the two hypo-

gastrics or by the division of the caudal vein, a coccygeo-mesenteric arises, which receives vessels from the cloaca and large intestine, and is continued along the mesentery to join the hepatic portal system.

As there are rarely any valves in the renal portal veins, the blood from the viscera and hind-limbs can pass freely either through the iliac veins and thence to the inferior vena cava, or through the coccygeo-mesenteric vein to the hepatic portal system.

The epigastric vein of the bird takes blood from the fat-laden sheet or great omentum which covers the abdominal viscera. It leads not into the liver, but into one of the hepatic veins.

Associated with the blood-vascular system, there is a lymphatic system with a few lymphatic glands. The spleen lies on the right side of the proventriculus, the paired thyroid lies beside the origin of the carotid arteries, and a paired thymus is found in young birds in the neck region.

Respiratory System.—The important facts are, that there is as yet no diaphragm, that some of the bronchial branches in the lungs are continued into adjacent air-sacs, that expiration is a more active process than inspiration.

The nostrils lie at the base of the beak overlapped by the cere. Only in the kiwi are they at the tip of the beak.

The trachea is strengthened by bony rings, and is moored to the sternum by two sterno-tracheal muscles. It has a larynx at its anterior end, and a syrinx at its lower end where the bronchi diverge. The bronchial tubes branch in a sort of tree-like fashion in the lungs. These lie attached to the dorsal wall of the thorax, indented by six of the ribs, and are covered with pleural membrane on their ventral surface only.

Around the lungs, and connected with the ends of some of the bronchial tubes, are nine air-sacs, four being lateral and one median. In order from behind forwards, lie posterior or abdominal sacs, the posterior thoracics, the anterior thoracics, the cervicals, and the interclavicular in the middle line in front. The anterior and posterior air-sacs are continuous with air-spaces in the bones.

Excretory System.—The kidneys are three-lobed, and lie embedded in the ilia. They receive blood from the dorsal

aorta by renal arteries, and the filtered blood leaves them by renal veins which unite, as already explained, with femorals and renal portals to form the iliac veins, or, we may almost say, the inferior vena cava. But there can be little doubt that the kidney also receives venous blood from the sciatic and other posterior veins. In other words there is a renal portal system.

The waste-products, consisting for the most part of urates, pass in semi-solid form down the ureters into the median compartment of the cloaca.

In front of each kidney, at the base of the iliac vein, there lies a supra-renal body of unknown functional significance.

Reproductive System.—The testes lie in front of the kidneys. They increase in size before the breeding season.

The spermatozoa pass from each testis into a vas deferens, which lies to the outside of the corresponding ureter. The vasa deferentia, slightly convoluted when full of sperms, open separately into the median compartment of the cloaca.

In the adult pigeon, and in most birds, there is only one ovary; that of the right side atrophies very early in life. We do not know the reason of this. The right oviduct is represented by a small rudiment close to the cloaca.

The ovary is covered with follicles containing ova at various stages of ripeness. As these ova become dilated with yolk and otherwise mature they burst from the ovary, and are caught by the dilated end of the oviduct. The first part of the duct is narrow, and there the ova may be fertilised; the second part is wide and glandular, secreting the white of egg; in the third region, which is muscular and glandular, the shell of the egg is made. In sexual union the cloaca of the male is closely apposed to that of the female; only in a few cases (in ducks and some other aquatic birds and in the Ratitæ), is there a special copulatory organ.

Development of the Chick.

(Summarised from Foster and Balfour's "Elements of Embryology."

The ovum of the fowl, when it has burst from the ovary, and has been caught by the dilated end of the oviduct, is a large spherical body, consisting for the most part of yolk, but bearing at one region a small

disc of formative protoplasm, in the midst of which lies the nucleus or germinal vesicle.

In the upper portion of the oviduct, the ovum is fertilised, and as it passes down the duct it becomes surrounded, first by white of egg or albumen, and afterwards by shell-membranes and a shell.

The fully-formed egg is surrounded by a porous shell of carbonate of lime. Within this is a double shell-membrane, the two layers of which are separated at the broad end of the egg to form an air-chamber. This chamber grows larger as development proceeds, and is of some importance, in connection with respiration, as an intermediate region between the embryo and the external medium. Within the inner shell-membrane lies the white of egg, consisting of alternate denser and more fluid layers of albumen. It is evident that shell and shell-membranes and albumen are extrinsic additions to the ovum proper, which, consisting mostly of yellow yolk, lies surrounded by a vitelline membrane in the midst of the albumen. From the vitelline membrane, membranous shreds called chalazæ extend in the albumen towards either end of the egg. The yolk is not homogeneous, but includes, besides the predominant yellow yolk, what is called white yolk. This consists of a central flask-shaped mass, and of several thin layers concentrically arranged in the substance of the yellow yolk. The stalk of the flask-shaped mass expands on the surface of the yolk as a funnel-shaped disc, overlying which is the area of formative protoplasm, which has already begun to segment.

As the ovum is heavily laden with yolk, and as the formative protoplasm lies at one pole, the segmentation must be meroblastic and discoidal. It begins in the lower part of the oviduct, and is exceptional in being somewhat asymmetrical. By the time the egg is laid, the segmented area or blastoderm has begun to be differentiated, showing an uppermost single layer of epiblast, and a lower hypoblast of larger cells in several layers. The hypoblast is separated by a slight cavity from the yolk, in which nuclei appear, comparable to the yolk-nuclei noticed in connection with the development of Elasmobranchs.

Viewed from above, the segmented area or blastoderm appears as a circular disc, the central part—known as the area pellucida—being distinguishable by its greater transparency from the darker peripheral ring or area opaca.

The blastoderm extends over the yolk, chiefly by the increase of the area opaca. Over most of the area pellucida, which assumes an oval form, the epiblast becomes two layers deep. The posterior region of the area pellucida becomes opaque, and this opacity is soon replaced by a dark median streak extending forwards. This linear streak appears to be homologous with what in simple cases would be the blastopore, or aperture of the gastrula; but it is difficult to prove this without an explanation more detailed than is possible in an elementary work like this. The opacity of the primitive streak is due to a thickening of the blastoderm by multiplication of cells, some of which must be regarded as mesoblastic.

In the line of the primitive streak, about the middle of its course, a shallow groove appears—the primitive groove. From the sides of the primitive streak, two wings of mesoblast extend to the limits of the area pellucida.

In the region in front of the primitive streak, traces of the embryo begin to appear. The hypoblast becomes in the middle line continuous with the front end of the primitive streak, and defines the future hind end of the embryo. The mesoblast of the embryo originates as two lateral plates split off from the hypoblast, and simultaneously the rudiment of the notochord appears as a median plate.

Very shortly afterwards, the median line of the epiblast in front of the primitive streak becomes differentiated into a medullary plate, and soon into a medullary groove whose folds will unite to form the medullary canal.

Before the closure of the medullary canal, the segments or somites of mesoblast begin to be formed.

As in other cases, the epiblast gives origin to the medullary canal (the brain and spinal cord and their outgrowths), and to the epidermis: the hypoblast lines the alimentary canal, which becomes a closed tube as the embryo is constricted or folded off from the subjacent yolk-sac: the mesoblast is divided into vertebral plates which form the backbone, and lateral plates which form the somatic and splanchnic musculature and other structures.

It may be interesting, however, to notice some of the steps of progress which characterise the first few days of incubation.

(1) By the end of the first day of incubation, the changes above described—up to the formation of the first mesoblastic somites—have usually taken place.

(2) During the second day, the embryo becomes more markedly constricted off from the yolk-sac. "Its long axis is placed at right angles to that of the egg, and the broad end of the egg is on the left side of the embryo." The three vesicles of the brain, the optic outgrowths, the involutions which form the ear, the first hints of cranial flexure, the heart, the growing amnion, are now apparent.

(3) During the third day, the embryo turns so as to lie partly on its left side, and the internal changes are very important. The cranial flexure is marked, the yolk-sac circulation is completed, four visceral clefts and five visceral arches appear, the optic cup and the lens are formed, the ear-sacs are closed, the nasal pits develop, the parts of the brain are more differentiated, the stomatodæum, mesenteron, and proctodæum form a complete gut, the lungs, liver, and pancreas arise as outgrowths of the mid-gut, and so on.

(4) Some of the chief events of the fourth day, are the increase of the cranial and body flexures, the formation of the limb-buds, the outgrowth of the allantois from the end of the mesenteron, the appearance of primitive ova in the germinal epithelium.

(5) During the fifth day, the allantois grows, the chondrocranium is formed, the limbs become more distinct, the auricles are separated, the spinal cord begins to be divided by fissures.

(6) During the sixth day, the distinctively bird-like characters begin to appear.

The amnion, which is completely closed on the fourth day, increases in size, and on the seventh day is of very considerable dimensions. The cavity between its folds is filled with fluid, and rhythmical contractions of the amnion rock the embryo to and fro.

The allantois grows very rapidly, and forms, by the sixth or seventh day, a large flattened sac, covering the right side of the embryo, and continuing to spread between the folds of the amnion.

The allantois becomes very vascular, and spreads over the yolk-sac "as a flattened bag filled with fluid;" it secures the respiration of the embryo by gaseous interchange with the surrounding medium.

The white of egg diminishes very rapidly, especially after the sixth day. After the tenth day, the yolk also begins to diminish rapidly, being absorbed by the blood-vessels in the walls of the yolk-sac.

By the eleventh day, the body of the embryo may be said to be completed. It is still connected to the yolk-sac by a solid vitelline stalk, which, along with the stalk of the allantois, forms the umbilical cord.

On the third day, the blood is aerated in the capillaries of the yolk-sac; on the fifth or sixth day, the allantois supplements the yolk-sac as a respiratory organ; afterwards, the whole of the respiration is secured by the allantois; finally, the chick begins to use its lungs. With these changes, important alterations in the vascular system are necessarily connected.

As early as the sixth day, movements are exhibited by the limbs of the embryo. "They cannot be of any great extent until the fourteenth day, for up to this time, the embryo retains the position in which it was first formed, viz., with its body at right angles to the long axis of the egg. On the fourteenth day, a definite change of position takes place; the chick moves so as to lie lengthways in the egg, with its beak touching the chorion (or outer fold of the amnion) and the shell-membrane, where they form the inner wall of the rapidly increasing air-chamber."

"On the twentieth day, or thereabouts, the beak is thrust through these membranes, and the bird begins to breathe the air contained in the chamber. Thereupon the pulmonary circulation becomes functionally active, and at the same time blood ceases to flow through the umbilical arteries. The allantois shrivels up, the umbilicus becomes completely closed, and the chick, piercing the shell at the broad end of the egg with repeated blows of its beak, casts off the dried remains of allantois, amnion, and chorion, and steps out into the world."

Classification of Birds.

Order 1. Saururæ. Ancient extinct birds, with reptilian affinities more marked than in any living forms.

The oldest known bird is *Archæopteryx*, remains of which have been found in the Solenhofen slates in the Upper Oolite (Jurassic) of Bavaria. "The stone is so fine grained that, besides the bones of the wings, the furculum or merrythought, the pelvis, the legs, and the tail, we have actually casts or impressions on the stone (made when it was as yet only soft mud) of all the feathers of the wings, and of the tail."

This link between Birds and Reptiles seeems to have been a land bird about the size of a crow. It had feathers and also teeth. In the fossil specimen the feathers are confined to the wings, legs, and tail, those on the head, neck, and trunk, having perhaps fallen off. Each joint of the long tail bears a pair of lateral feathers—a unique arrangement. The

vertebræ are biconcave; the ribs are very thin; the sternum is broad, and perhaps had a keel; there seem to have been abdominal ribs. The three digits of the hand have separate metacarpals, and are clawed; the bones of the pelvis are not fused, there are only a few sacral vertebræ, perhaps there was an ischial symphysis, there is a complete fibula with its distal portion in front of the tibia, the metatarsals are incompletely fused; the tail was long like that of a lizard, with about a score of vertebræ, and no ploughshare bone.

Of an American bird, *Laopteryx*, also found in Jurassic strata, very little is certainly known.

Order 2. Ratitæ. Running-Birds with raft-like unkeeled breast-bone.

(*a*) With teeth. Odontolcæ.—Extinct types from N. American Cretaceous strata.

Hesperornis, the only certain type, seems to have been like a swimming Ostrich. Its sharp teeth, sunk in a groove, suggest a carnivorous habit; it had four toes all turned forward; its tail of about a dozen vertebræ and without a ploughshare bone, perhaps served as a rudder in the water. The fore-limb is much reduced; the vertebræ are like those of modern birds. The rami of the lower jaw were separate. One species measures between five and six feet in length.

(*b*) Without teeth.

The African Ostrich (*Struthio*) is represented by two or three species, at home in the plains and deserts of Africa, and notable for their size, swiftness of foot, and beauty. There are but two toes, the third and the fourth, the latter clawless. The pubes form a ventral symphysis. The ostrich is monogamous, and at the breeding season the hen lays its eggs, at intervals of two days, in a hollow dug out in the sand by the male. The eggs are incubated by the parents alternately, the male sitting during the night, but in the hottest regions they are sometimes left during part of the day simply covered by the sand.

The American Ostrich (*Rhea*) is represented by three species in the S. American Pampas. In the *Rhea* there are three toes, all clawed, and the ischia form a ventral symphysis. Only here among Ratitæ is there a well-developed syrinx. The male excavates a shallow nest in the ground, and there, surrounded by a few leaves and grasses, the numerous eggs are usually laid. It seems that the male bird alone hatches the eggs. Single eggs are often laid here and there on the plains, but these are not incubated.

The Emu (*Dromæus*) is represented by two species in Australian deserts and plains. The fore-limb is greatly reduced, the feathers have long after-shafts. Nearly related are the Cassowaries (*Casuarius*) living in the Austro-Malayan region, eight species in the Papuan Islands, one in N. E. Australia, and one in Ceram. They live in the forests and scrub. The fore-limb is very small, with the shafts of the wing feathers reduced to spines; the ordinary feathers have long after-shafts. On the top of the skull there is a horny helmet covering a core of light spongy bone; this protects the bent head as the bird rushes through the scrub. There are three toes, the inner one with a long sharp claw—a formidable weapon.

The Kiwi (*Apteryx*) forms a very distinct genus of Ratitæ, represented by four species, restricted to New Zealand. It is not larger than a hen, and has simple hair-like or bristle-like feathers, a long bill and terminal nostrils, a very rudimentary wing and no clavicles, and no distinct tail feathers. It is a nocturnal bird, swift and noiseless in its movements, feeding in great part on earthworms. The egg is very large for the size of the bird.

Among the extinct forms are the gigantic Moas (*Dinornis*), which seem to have been exterminated in New Zealand in comparatively recent times (in all likelihood, during the latter part of the eighteenth century). The fore-limbs were almost completely reduced, the hind-legs were very large, and some forms attained a height of ten feet or even more.

Another recently lost order of giant birds is represented by remains of *Æpyornis* found in Madagascar. Some of these indicate birds as large as ostriches, but eggs have been found holding six times as much as that of ostrich.

We must think of the Ratitæ, according to W. K. Parker, as "overgrown, degenerate birds that were once on the right road for becoming flying fowl, but through greediness and idleness never reached the 'goal,' went back, indeed, and lost their sternal keel, and almost lost their unexercised wings."

Order 3. Carinatæ. Flying-Birds with a keeled breast-bone.

(*a*) With teeth. Odontornithæ. Extinct Carinate birds, with biconcave vertebræ, with teeth in distinct sockets, with the rami of the lower jaw loosely united. The only certain example is *Ichthyornis* from the N. American Cretaceous strata.

(*b*) Without teeth. The flying-birds of post-Cretaceous times, and of to-day.

The detailed classification of Birds is difficult. There are so many that ornithologists have not yet been able to decipher all their relationships. It is only of recent years that anatomists like Huxley, and embryologists like Parker, have placed the classification on a secure foundation.

For though the old classification of birds into snatchers (Raptores), perchers (Insessores), climbers (Scansores), scratchers (Rasores), stilt-walkers (Grallatores), and swimmers (Natatores), was interesting and suggestive, yet it is easy to understand that an arrangement of this sort may be misleading, since birds of entirely different structure may have similar habits.

Huxley classified birds according to the structure of their skulls, and though this might seem a one-sided method of classification, its naturalness depends, as Parker notes, on the striking fact that "the structure of the skull and face govern the whole body, as it were; every other part of the organism corresponds to what is observable there."

Huxley's classification, slightly altered by Parker, is as follows:—

A. The vomer broad behind, and interposing between the pterygoids, the palatines, and the basisphenoidal rostrum:—DROMÆOGNATHÆ.

The Tinamous.

B. The vomer narrow behind; the pterygoids and palatines articulating largely with the basisphenoidal rostrum.

a. The maxillo-palatines free.

1. The vomer pointed in front:—SCHIZOGNATHÆ. The plovers, gulls, penguins, cranes, fowls, sand-grouse, pigeons, the hoatzin, the goat-suckers, the humming-birds.
2. The vomer truncated in front:—ÆGITHOGNATHÆ. The passerines, swifts, and the hemipods.
3. The vomerine halves permanently distinct, and the maxillo-palatines arrested:—SAUROGNATHÆ. The woodpeckers.

b. The maxillo-palatines united:—DESMOGNATHÆ. The birds of prey, parrots, cuckoos and kingfishers, ducks and geese, flamingoes, storks, and cormorants.

We shall now give a list of the different orders of Carinate birds, as at present recognised by P. L. Sclater, Newton, and other authorities.

Passeres:—the largest order, with about six thousand species—more than half the total number of known birds, including thrushes, wrens, warblers, tits, swallows, creepers, finches, crows, pies, jays, starlings, and birds of paradise.

Picariæ:—a somewhat heterogeneous order, of about eighteen hundred species, characteristically tropical, including cuckoos, plantain-eaters, the oil-bird (*Steatornis*), *Podargus*, goat-suckers or night-jars, bee-eaters, mot-mots, kingfishers, hornbills, hoopoes, toucans, woodpeckers, wrynecks, trogons, swifts, and humming-birds.

Psittaci:—parrots, cockatoos, and their allies.

Striges:—the owls.

Accipitres:—the diurnal birds of prey, such as eagles, hawks, falcons, and vultures.

Steganopodes:—the pelicans, frigate-birds, albatrosses, cormorants, gannets, and darters.

Herodiones:—the herons, storks, spoon-bills, and ibises.

Odontoglossæ:—the flamingoes.

Palmedeæ:—the American screamers.

Anseres:—the ducks and geese.

Columbæ:—the pigeons, and the exterminated Dodo and Solitaire.

Pterocletes:—the sand-grouse, *Pterocles* and *Syrrhaptes*.

Gallinæ:—the pheasants, fowls, grouse, curassows, and megapodes.

Opisthocomi:—including only one bird, *Opisthocomus*,—an "archaic curassow" with remarkable reptilian affinities.

Fulicariæ:—the rails, coots, and water-hens.

Alectorides:—the cranes, and perhaps the bustards.

Limicolæ:—the curlews and plovers.

Gaviæ:—the gulls and terns.

Pygopodes:—the guillemots and grebes, divers and auks (including the exterminated great auk).

Turbinares:—the petrels.

Impennes:—the penguins.

Crypturi:—the Tinamous.

Some Contrasts between modern Ratitæ and modern Carinatæ.

RATITÆ.	CARINATÆ.
Running-Birds, with wings more or less degenerate and unused in flight, with a keelless raft-like breast-bone.	Flying-Birds, with wings almost always well exercised in flight, with a keeled breast-bone. (The keel is rudimentary in the New Zealand parrot *Stringops*, in the exterminated Dodo (*Didus*), and in the extinct *Aptornis*—one of the rails. The penguins do not fly at all, the Tinamou, the Hoatzin, and some other birds, fly very little.)
The skull is dromæognathous, the palatines not articulating with the basisphenoidal rostrum.	Except in the Tinamous, the skull is never dromæognathous, the palatines articulating with the basisphenoidal rostrum.
The sutures in the skull remain for a long time distinct.	The sutures in the skull almost always disappear very early.
The long axes of the adjacent portions of the scapula and coracoid lie almost in the same line, or form a very obtuse angle.	The scapula and coracoid meet at a sharp angle.
The clavicles are small or absent.	The clavicles are in most cases very well developed.
The ilium and ischium are not united behind.	The ilium and ischium unite, enclosing a sciatic foramen.
The feathers of the adult have free barbs.	The barbs of the feathers are generally united.

Pedigree of Birds.

Birds have many structural affinities with Reptiles, the ancient Dinosaurs present approximations to Birds, the extinct flying Pterodactyls show that it was possible for flight to be developed among Reptiles, the oldest bird—*Archæopteryx*—is in many ways a connecting-link between the two classes, and the development of some Birds reveals many remarkable resemblances with that of Reptiles,—therefore, with the strength of the general argument for evolution to corroborate us, we are safe in concluding that Birds evolved from a Reptile stock.

As we have already emphasised the common characters which unite Birds and Reptiles in the alliance Sauropsida, and have noticed the importance of Dinosaurs and of

Archæopteryx, let us give two illustrations of the manner in which embryology confirms the evolution theory.

Speaking of his work on the development of the fowl, W. K. Parker wrote in 1868:—"Whilst at work I seemed to myself to have been endeavouring to decipher a *palimpsest*, and one not erased and written upon again just once, but five or six times over. Having erased, as it were, the characters of the culminating type—those of the gaudy Indian bird—I seemed to be amongst the sombre Grouse; and then, towards incubation, the characters of the Sand-grouse and Hemipod stood out before me. Rubbing these away, in my downward work the form of the Tinamou looked me in the face; then the aberrant Ostrich seemed to be described in large archaic characters; a little while, and these faded into what could just be read off as pertaining to the Sea-Turtle; whilst underlying the whole, the Fish, in its simplest Myxinoid form, could be traced in morphological hieroglyphics."

More than twenty years later, the same accomplished embryologist described the development of the "Reptilian Bird"—*Opisthocomus cristatus*. In this form the unhatched chick has a paw-like hand, three clawed fingers and a rudiment of a fourth, a wrist of numerous carpal elements, and many other features suggestive of reptilian descent. It is not surprising, then, that to Parker, a bird seemed as "a transformed and, one might even say, a glorified Reptile, the quasi-imago of the reptile, which takes the place of an active pupa, the fish doing duty, in the present economy of nature, as the larva."

It is likely that Birds arose from the Dinosaurian stock, but by what steps and under what impulses we do not know. To one it is enough to say that the evolution was accomplished gradually in the course of natural selection by the fostering of fit variations and the elimination of the disadvantageous; to another it seems that the incipient birds were "*fevered* representatives of reptiles, progressing in the direction of greater and greater constitutional activity;" but both these suggestions leave much in the dark, leave us still to "wonder how the slow, cold-blooded, scaly beast ever became transformed into the quick, hot-blooded, feathered bird, the joy of creation."

CHAPTER XXV.

CLASS MAMMALIA.*

BIRDS and Mammals are the two highest classes of Vertebrates. As they have evolved along very different lines, Birds possessing the air and Mammals the earth, we cannot say that either class is the higher. But apart from the fact that man himself is zoologically included among Mammals, this class is superior to Birds in two ways,—in brain development and in the relation between mother and offspring. In most Mammals there is a prolonged organic connection between the mother and the unborn young, and perhaps Robert Chambers was right in suggesting that this prolonged gestation was one of the primary factors in progress, somehow connected, it may be, with the development of large brains. Moreover, it is characteristic of Mammals that the young are nourished after birth by their mother's milk, and it has been reasonably suggested that the prolonged infancy of young Mammals was one of the most important factors in the evolution of gentleness. It is well to notice that one of the essential conditions of the survival and success of Mammals, and of Birds also, has been the affectionate carefulness and sacrifice of the mothers. We may find in the term Mammalia, which Linnæus first applied to the class, a hint of the idea that in the evolution of these forms of life, the mothers led the way.

General Survey of Mammals.—There are three grades of Mammalian development.

* In writing the systematic part of this chapter I have been especially indebted to the "*Introduction to the Study of Mammals*," by W. H. Flower and R. Lydekker.—(Lond., 1891.) From this valuable work have been taken many of the statements of general characters and some sentences within quotation marks.

(*A.*) The duckmole (*Ornithorhynchus*) and the porcupine ant-eater (*Echidna*) differ from all other Mammals in many ways. The young are hatched outside of the body; in other words, the mothers are oviparous. The brain seems but poorly developed when compared with that of other Mammals. Some of the characteristics of the skeleton and other structures suggest Reptilian affinities. To this small sub-class, the titles Monotremata, Ornithodelphia, and Prototheria are applied.

(*B.*) The kangaroos and bandicoots, phalangers and opossums, and the like, form the second sub-class, the members of which are called Marsupials. In these the young are born prematurely, after a short gestation during which the organic connection between the mothers and the young is comparatively slight. Most female Marsupials have an external pouch or marsupium, to which the tender young are transferred, and within which they are nourished and protected for some time. Moreover, the brains even of the most intelligent Marsupials are not so well developed as those of higher Mammals. To this sub-class, the titles Marsupialia, Didelphia, and Metatheria are applied.

(*C.*) In all the other Mammals there is a close connection or placenta vitally uniting the unborn young to the mother. It is among these placental Mammals that the brains begin to be much convoluted,—as it were, wrinkled with thought. To this sub-class, including sloths and ant-eaters (Edentata), sea-cows (Sirenia), hoofed-animals (Ungulata), Cetaceans, Rodents, Carnivores, Insectivores, Bats, Lemurs, and Monkeys, the titles Placentalia, Monodelphia, and Eutheria are applied.

Let us try to take a bird's-eye view of the whole series, and especially of the numerous orders of placental Mammals. Among these it seems likely that the Edentata and Sirenia should be placed lowest, for many of their characteristics are distinctly old-fashioned. The rest may be provisionally grouped in three sets, perhaps representing the three main lines of evolution.

On one side let us place the great series of hoofed animals or Ungulata, including (*a*) those with an even number of toes (Artiodactyla), such as pigs, hippopotamus, camels, cattle, and deer; (*b*) those with an odd number of toes (Perissodactyla), such as tapir, rhinoceros, and horse; (*c*) the

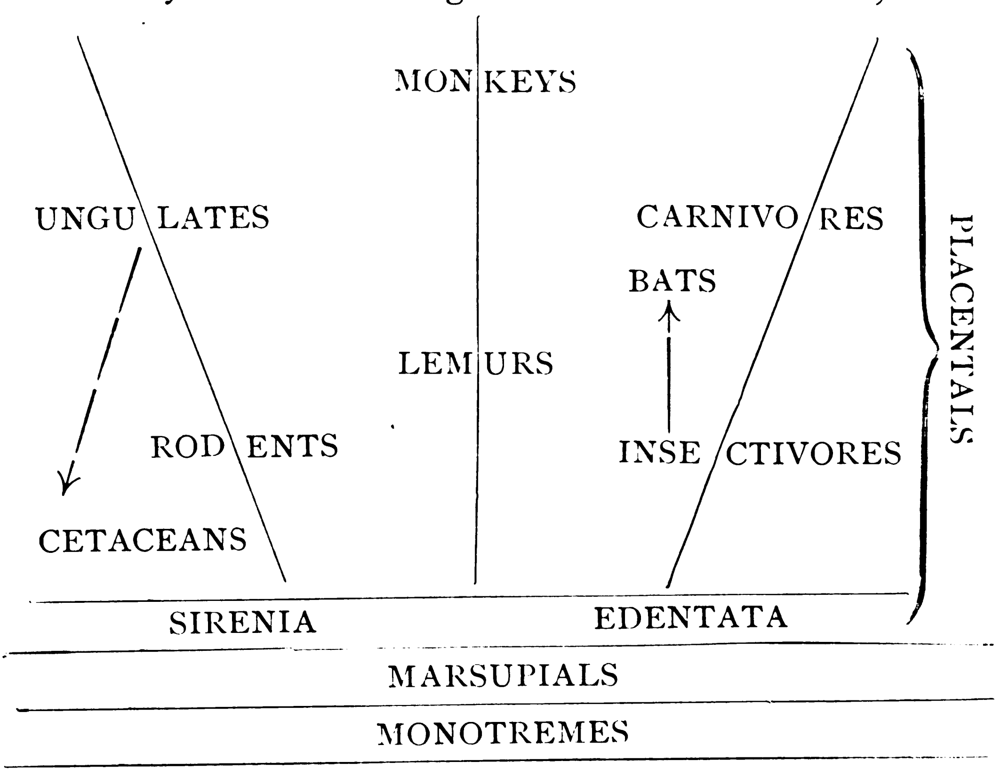
elephants (Proboscidea); (*d*) the Hyraxes (Hyracoidea). And beside the Ungulata it seems legitimate to rank the whales and dolphins (Cetacea), and the rabbits and hares, rats and mice, and other forms included in the order Rodentia.

On the other side let us place the great series of Carnivora, such as cats, dogs, bears, and seals. Beside these may be ranked the Insectivora, such as hedgehog, mole, and shrew, and the bats or Chiroptera, which seem to be specialised Insectivores.

In the middle let us place the series which, beginning with the Lemurs, leads through various grades of monkeys to a culmination in man. Among the monkeys are the small and simple marmosets, the flat-nosed American monkeys, the dog-like apes of the Old World, and the anthropoid apes, which most nearly approach man.

But it must be carefully noted that these orders are often linked by extinct types. Thus, to take in the meantime one instance only, it is believed by some that the extinct *Phenacodus* has affinities with Ungulates, Carnivores, and Lemurs, suggesting the unity of the three series which we have dististinguished.

We may summarise the general classification thus;—



General Characters.

Form.—All Mammals are quadrupeds, except the Cetaceans and Sirenians, in which the hind-limbs have disappeared, leaving at most only internal vestiges. In most there is a distinct neck between the head and the trunk, and the vertebral column is usually prolonged into a tail.

Skin.—Hairs are never entirely absent. Usually they form a thick covering for the skin, but they are scanty in Sirenians and in the hippopotamus, and almost absent in Cetaceans, in which they are sometimes restricted to very early stages in life. The skin has abundant sebaceous and sudorific glands. In the female, milk-giving or mammary glands develop, apparently as specialisations of sebaceous glands, except in Monotremes, in which they seem nearer to the sudorific type.

Muscular System.—A complete muscular partition or diaphragm separates the cavity containing the heart and lungs from the abdominal cavity, and as it alters the size of the chest cavity, it is of great importance in respiration.

Skeletal System.—All the important bones have distinct terminal ossifications or epiphyses, absent, however, in the vertebræ of Monotremes and Sirenia. The centra of the vertebræ have generally flat faces, and there are always seven cervical vertebræ, except in the manatee and the two-toed sloth (*Cholœpus hoffmanni*), which have six; the three-toed sloth (*Bradypus tridactylus*), which has nine; and in the pangolin (*Manis*), which has sometimes eight,—variations which, it will be observed, are limited to the two most old-fashioned orders of placental Mammals.

The bones of the skull are firmly united by sutures, which generally persist. Only the lower jaw, the ear-ossicles, and the hyoid are movable. There are two occipital condyles, as in Amphibians; the lower jaw on each side consists, in adult life, of a single bone which works on the squamosal, the quadrate which intervenes in Sauropsida having disappeared, or been shunted out of place to become one of the ear-ossicles. For it is one theory of the three ossicles—malleus, incus, and stapes—which connect the drum with the inner ear, that they correspond respectively to the articular,

quadrate, and columella or hyo-mandibular of other Vertebrates. The otic bones fuse to form a compact periotic. A bony palate, formed from premaxillæ, maxillæ, and palatines, separates the buccal cavity from that of the nasal passages. In most cases there are teeth, borne in sockets by the premaxillæ, maxillæ, and mandible.

Except in Monotremes, the coracoid is represented merely by a small process from the scapula, forming part of the glenoid cavity in which the head of the humerus works, but not reaching the sternum. The latter is divisible into three regions;—(*a*) a presternum with which the interclavicle is fused, and with which the clavicles (if well-developed) articulate, (*b*) a mesosternum divided into segments, with which the sternal parts of the ribs articulate, and (*c*) a xiphisternum, often cartilaginous. There are generally two sacral vertebræ, with which several caudals, and more rarely a lumbar, may be fused. The ilia slope downwards and backwards, the ischia have no symphysis, but the pubes are almost always united ventrally.

Nervous System.—The cerebral hemispheres have usually a convoluted surface, and always cover over the optic thalami and the optic lobes (now four-fold corpora quadrigemina), and in higher forms the cerebellum as well. The commissural system is well-developed, being especially represented by a large corpus callosum, except in Monotremes and Marsupials, in which the anterior commissure is large and the corpus callosum incomplete. There is also an important set of longitudinal fibres called the fornix.

Alimentary System.—Except in the Monotremes, in which there is a cloaca, the food-canal ends separately from the urinogenital aperture.

Circulatory System.—The heart is four-chambered, and the temperature of the blood is high, though less than that of Birds. There is but one aortic trunk, which curves over the left bronchus. The red blood-corpuscles are, when fully formed, non-nucleated, and are circular in outline, except in the Camelidæ where they are oval.

Respiratory System.—The lungs are invested by pleural sacs, and lie freely in the cavity which is bounded posteriorly by the diaphragm. Within the lungs the bronchial tubes fork repeatedly into finer and finer branches. At the top

of the trachea there is a complex larynx, the organ of voice.

Excretory System.—The kidneys are generally compact and rounded bodies; the ureters open into the bladder, except in Monotremes in which they enter a urinogenital sinus. Except in Monotremes, the outlet or urethra of the bladder unites in the male with the genital duct, to form a urinogenital canal; while in the female, except in Monotremes and a few other cases, the urethra and the genital duct open into a common vestibule.

Reproductive System.—In the more primitive mammals the testes lie in the abdomen; in the majority they descend permanently (in a few cases temporarily) into a single or paired scrotal sac, lying, except in Marsupials, behind the penis.

The ovaries are small. Except in Monotremes, the genital ducts of the female are differentiated into (*a*) fallopian tubes, which catch the ova as they burst from the ovaries; (*b*) a uterine portion in which the young develop; and (*c*) a vaginal portion ending in the urinogenital aperture. In Monotremes the two ducts are simple, and open separately into the cloaca; in Marsupials there are two uteri and two vaginæ; in Placental Mammals the uterine regions are more or less united, and the vaginal regions are always fused.

Development.—In Monotremes the eggs are large and rich in yolk; in all others they are small and almost yolkless. In the ovary each ovum lies embedded in a nest of cells, within a swelling or Graafian follicle which eventually bursts and liberates the ovum. In Monotremes the segmentation is necessarily meroblastic, in other cases it is holoblastic. As in Sauropsida there are two fœtal membranes—the amnion and the allantois, both of which share in forming the placenta of the Placental Mammals.

Parturition.—The Monotremes are oviparous; the Marsupials bring forth their young prematurely after a short gestation; the Placental Mammals have a longer gestation, during which the young are vitally connected to the wall of the uterus by means of the placenta.

General Life of Mammals.—Most Mammals live on dry land. The bats, however, have the power of flight, and not a few forms, belonging to diverse orders, are able to take long swooping leaps from tree to tree. Thus, there are "flying-

phalangers," such as *Petaurus*, among Marsupials; "flying-squirrels," such as *Pteromys*, among Rodents; "flying-lemurs" (*Galeopithecus*), allied to Insectivores. Not a few are aquatic,—all the Cetaceans, the two Sirenians, and the Pinniped Carnivores, such as seals and walruses; while water-voles, beavers, otters, polar bear, and many others are also at home in the water. Burrowers are well-represented by moles and rabbits; arboreal forms by squirrels and monkeys.

As to diet, man, most monkeys, pigs, and many others, may be called omnivorous; kangaroos, hoofed animals, and most rodents are herbivorous; the echidna, the ant-eaters, hedgehogs and shrews, and some bats are insectivorous; most of the Carnivora are carnivorous; dolphins and seals feed chiefly on fishes; but in most cases the diet varies not a little with the available food-supply.

The struggle for existence among Mammals is sometimes keen among fellows of the same kind; thus the brown rat (*Mus decumanus*) tends to drive away the black rat (*M. rattus*), but stress, due to over-population, is sometimes mitigated by migration, as in the case of the lemmings. The struggle seems to be keener between foes of different kinds, between carnivores and herbivores, between birds of prey and small mammals; but combination for mutual defence often mitigates the intensity of the conflict. Teeth and claws, hoofs and horns are the chief weapons, while the scales of pangolins, the bony shields of armadillos, the spines of hedgehogs and porcupines, and the thick hide of the rhinoceros may be regarded as protective armature. In keeping their foothold some mammals are helped by the harmony between their colouring and that of their surroundings; thus, the white Arctic fox and hare are inconspicuous on the snow, the striped tiger is hidden in the jungle, and many tawny animals harmonise with the sandy background of the desert.

The majority of Mammals are gregarious, witness the herds of herbivores, the cities of the prairie-dogs, the packs of wolves, the schools of porpoises, the bands of monkeys. Combinations for attack and for defence are common; sentinels are posted and social conventions are respected; such migrations as those of the lemming and reindeer are char-

acteristically social. In the beaver village and among monkeys there is combined industry, and their communal life seems prophetic of that sociality which is distinctively human.

Among Birds, mates are won by beauty of song and plumage; Mammals not less characteristically woo by force. Rival males fight with one another, and are usually larger and stronger than their mates. The antlers of male deer, the tusk of the male narwhal, the large canine teeth of boars illustrate secondary sexual characters useful as weapons. But manes and beards, bright colours and odoriferous glands are often more developed in the males than in the females, and may be of advantage in the rough mammalian courtship. At the breeding season, a remarkable organic reaction often affects the animal, the timid hare becomes a fierce combatant, and love is often stronger than hunger. The courtship of Mammals is usually like a storm—violent but passing; for, after pairing, the males return to their ordinary life, and the females become maternal. Some monkeys are faithfully monogamous; and exceptional pairs, such as beavers and some antelopes, remain constant year after year; but this is not the way of the majority.

The duckmole lays eggs and brings up her young in the shelter of the burrow; the echidna has a temporary pouch. In Marsupials the time of gestation is very short, and there is no truly placental union between the unborn young and the mother. When born, the young are very helpless, and are in most cases transferred to an external pouch or marsupium, within which they are nurtured. In Placental Mammals the gestation usually lasts much longer than in Marsupials,—its duration varying to some extent with the rank in the mammalian series, but there are great differences in the condition of the young at birth. "In those forms," Prof. Flower says, "which habitually live in holes, like many Rodents, the young are always very helpless at birth; and the same is also true of many of the Carnivora, which are well able to defend their young from attack. In the great order of Ungulates or Hoofed Mammals, where in the majority of cases defence from foes depends upon fleetness of foot, or upon huge corporeal bulk, the young are born in a very highly developed condition, and are able almost at

once to run by the side of the parent. This state of relative maturity at birth reaches its highest development in the Cetacea, where it is evidently associated with the peculiar conditions under which these animals pass their existence." The importance of prolonged infancy, as illustrated among monkeys, should be recognised in connection with the evolution of gentleness.

The maternal sacrifice involved in the placental union between the mother and her "fœtal parasite," in the prolonged gestation, in the nourishment of the young on milk, and in the frequently brave defence of the young against attack, has been rewarded in the success of the mammalian race, and has been justified in the course of natural selection. But it is important to recognise that the maternal sacrifice—whatever its origin may have been—expresses a subordination of self-preserving to species-maintaining ends, illustrates that altruistic as well as egoistic activities have been factors in evolution.

History of Mammals.—As to the origin of Mammals we can only speculate. There are some remarkable resemblances between Monotremes and certain extinct Reptilian types, known as Anomodontia or Theromorpha, and these again exhibit affinities with the extinct Labyrinthodont Amphibians. Amphibians and Mammals agree in having two occipital condyles, small quadrates, large squamosals, and in certain characteristics of pectoral and pelvic girdles. Possibly the ancestral Mammals and the Anomodont Reptiles diverged from a common Amphibian stock.

The oldest known remains of Mammals are some fossils from Triassic rocks, and similar types have been found in Cretaceous and Jurassic beds; most of these Mesozoic fossils are but small pieces of small animals, and secure conclusions as to their nature are not readily reached. It is likely that future discoveries will make the record much less fragmentary. Many of the Mesozoic mammals belong to a group which has received the name of Multituberculata, on account of the longitudinal rows of tubercles on the back teeth. It is possible that these forms, e.g., *Plagiaulax*, *Tritylodon*, *Polymastodon*, should be ranked beside the Monotremes.

Other Mesozoic forms, such as *Dromatherium*, *Triconodon*,

Amphitherium, *Spalacotherium*, are often referred to the Marsupial series beside opossum, dasyure, and bandicoot.

The first certain remains of Placental Mammals are found in Eocene strata, and give evidence of the existence of generalised types connecting rather than referable to the modern orders. Many are characterised by the presence of three tubercles on the back teeth, and of five digits on the limbs, and by having brains relatively smaller than those of their modern successors.

Among extinct Tertiary types, we may especially notice the ground-sloths (e.g., *Megatherium*) and Glyptodonts allied to the modern Edentata, the Zeuglodonts included among Cetaceans, numerous ancestral Ungulates, and the Creodonts allied to modern Carnivores.

More detailed account of some of the structures of Mammals.

The Skin consists of a superficial epidermis derived from the outer or ectodermic layer of the embryo, and of a subjacent mesodermic dermis or cutis.

The most characteristic modification of the mammalian epidermis is the hair. Each hair arises from the cornification of an ingrowing epidermic papilla, surrounded at its base by a moat-like follicle, and nourished during growth by a vascular projection of the dermis.

Each hair consists of a spongy central part and a denser cortex, but there are many diversities of form and structure, such as short fur and long tresses, the soft wool of sheep and the bristles of pigs, the spines of hedgehog, porcupine, and echidna, the cilia of the eyelids and the tactile vibrissæ of the lips and cheeks.

The hair keeps the animal dry and warm; in the practically hairless Cetacea the layer of fat or blubber underneath the skin also serves to sustain the temperature of the body. Like feathers, hairs die away and are cast off, being replaced by fresh growths. A few mammals, such as the Arctic fox, the mountain hare, and the ermine, become white in winter, harmonising with the snow. In the case of Ross' lemming, we know that this change is directly due to the influence of the cold, and depends in great part on the appearance of gas-bubbles inside the hairs.

That the colouring is sometimes of protective advantage, we have already noticed; but in many cases no utilitarian interpretation can be read into the stripes and markings. Those of related species often form regular series, and are superficial outcrops of constitutional changes hardly to be analysed. Sometimes there is considerable change during

the lifetime of the animal, thus most young deer have spots, but only the Fallow and Axis deer retain these when adult. To an excess of pigment is due the variation known as melanism or blackness, *e.g.*, in black wolves and rabbits; to a dearth of pigment albinism is due, as in white mice and white elephants. In tropical countries the skin is sometimes very darkly coloured, as in Indian cattle, and many monkeys—especially males—are notable for the bright colours of the bare parts of the body.

Among other tegumentary structures are the scales which occur along with hairs on the pangolins (*Manis*), the scales on the tails of rats and beavers and some other forms; the thickened skin-pads or callosities on the ischia of apes, the breast of camels, the legs of horses; the nails, claws, or hoofs which ensheathe the ends of the digits in all mammals except Cetaceans. Unique is the armature of the armadillos, for it consists of bony plates developed in the dermis, overlaid by epidermic scales. The median solid horns of the rhinoceros are epidermic outgrowths, comparable to exaggerated warts; the paired horns of the Ruminants consist of epidermic sheaths covering outgrowths of the frontal bones, but extending far beyond these; the antlers of stags are outgrowths of the frontal bones, and, except in the reindeer, are cast and regrown each year, and possessed by the males only.

The skin of Mammals, unlike that of Birds, is rich in glands. Sebaceous glands are always associated with the hair-follicles, and sudorific or sweat glands are scattered over the skin.

Specialised glands are also very common, especially those which secrete some strongly odoriferous stuff, scenting which the animals recognise their fellows, their foes, and their prey. Often they are most developed in the males, and their activity increases at the pairing season.

Among the numerous special glands may be noted, those which are connected with a perforated spur on the hind-legs of male Monotremes, the sub-orbital glands of antelopes and deer, the anal glands of carnivores, the perineal glands of the civet, the preputial glands of the musk-deer and beaver, the inter-digital glands of the sheep.

Most characteristic, however, are the mammary glands, functional in female Mammals after parturition. They seem to be specialisations of sebaceous glands, except in Monotremes, in which they are nearer the sudorific type. They consist of branching tubes opening by one or several aper-

tures on the skin. From the white blood-corpuscles of the abundant vascular supply, and from a degeneration of the cells lining the glandular tubes, the milk is produced. It begins to be produced when the young are born, when, in Placental Mammals, the demand upon the mother through the placenta has ceased.

In Monotremes, the simple glands, compressed by muscles, open by several pores on a bare patch of skin. This is depressed into a slight cup from which the young lick the milk. In Marsupials, the glands open by teats or mammæ, generally hidden within a marsupium; and again the action of surrounding muscles forces the milk into the mouths of the young, which do not seem to be able to suck. An anterior prolongation of the larynx to meet the posterior nares establishes a complete air passage, and enables the young to continue breathing while they are being fed. "In the Cetacea, where the prolonged action of sucking would be incompatible with their subaqueous life, the ducts of the glands are dilated into large reservoirs, from which the contents are injected into the mouth of the young animal by the action of a compressor muscle." In all other Mammals the young suck the milk from the mammæ.

Dentition.—The teeth of Mammals are developed in the gums or soft membrane covering the borders of the premaxillæ, maxillæ, and mandibles. As in other animals, they are in part of epidermic, in part of dermic origin. In the course of their development their bases are enclosed in sockets formed in the subjacent bones.

In most teeth there are three or four different kinds of tissue. The greater part consists of dentine or ivory; outside of this there is a layer of very hard glistening enamel; in the interior there is a cavity which in growing teeth contains a gelatinous tissue or pulp, supplied by blood-vessels and by branches of the fifth nerve, and contributing to the increase of the dentine; lastly, around the narrowed bases or roots of the tooth, or between the folds of the enamel if these have been developed, there is a bone-like tissue called the crusta petrosa or cement.

The development of a tooth begins with the formation of an enamel-germ, an invagination of the ectodermic epithelium or epidermis. Beneath this germ a papilla of

the vascular mesodermic dermis is defined off as the "dentine germ." The crown of this papilla becomes hard, and the ossification proceeds downwards and inwards, while above the dentine crown the enamel begins to form a hard cap. Meantime the tissue around the base of the tooth-papilla becomes differentiated into an enclosing follicle or sac, from the inner layer of which the cement is developed. The pulp is but the uncalcified core of the papilla. When there are two sets of teeth, the enamel-germ which begins a tooth of the second set is a bud from the enamel-germ of its predecessor of the first set. Similarly in regard to the molars, of which there is never more than one set, the first molar has an independent origin, the enamel-germ of each of the others is budded from the molar immediately in front of it.

The base of a tooth may remain unconstricted, and the core of pulp may persist. Such a tooth goes on growing, its growth usually keeping pace with the rate at which the apex is worn away with use, and it is described as "rootless" and "with persistent pulp." The incisors of Rodents and of Elephants illustrate this condition.

In the development of most teeth, however, the base is narrowed and prolonged into a root or several roots which become firmly fixed in the socket. Through a minute aperture at the end of the root, blood-vessels and nerves still enter the pulp-cavity and keep the tooth alive, but as the limit of growth is reached the residue of soft pulp tends to disappear. Of these "rooted" teeth there are many kinds, differing in size and shape, in the number of roots, and in the period at which these are definitely established. Mammals also differ not a little in regard to the period at which the teeth—usually concealed at the time of birth—appear on the surface or cut the gum.

Some mammals have but one set of teeth. If one of them be lost or worn away, it cannot be replaced. These mammals, such as the sloths and the toothed whales, are called monophyodont. But most mammals have two sets of teeth,—a more important permanent set which is functional through the greater part of life, and a less important transient first set the members of which, often being developed during the period of sucking, are called milk-

teeth. Mammals with these two sets of teeth are called diphyodont. The milk-teeth may be shed, as in seals, before or shortly after birth, or they may remain, as in Ungulates, for a long time, being gradually replaced by the permanent set. A milk-tooth generally gives origin to a permanent tooth, but this is not invariably the case; moreover, the back teeth or molars are permanent teeth which have no direct predecessors in the milk-set.

In a few mammals, for instance in the dolphins, the teeth are very uniform, almost all alike from beginning to end. Such a dentition is called homodont, in contrast to the common heterodont dentition, in which the teeth are more or less markedly different in form and function. It is necessary now to consider these differences.

In the typical dentition of Mammals, there are forty-four permanent teeth, eleven on each side above and below. The eleven on each of the upper jaws, may be divided into four sets. Most anteriorly, associated with the premaxilla, are three simple, single-rooted teeth, usually adapted for cutting or seizing. These are called incisors. Posteriorly there are crushing or grinding teeth, whose crowns bear cusps or cones, or are variously ridged, and which have two or more roots associated with the maxilla. But of these grinders, the last three have no milk predecessors and are therefore distinguished as true molars, from the four more anterior, and often simpler premolars, which in diphyodont mammals have predecessors in the milk-set. Finally, the tooth just behind the incisors, that is to say, immediately posterior to the suture between premaxilla and maxilla, is distinguished as the canine, and is often long and sharp.

This classification of teeth is in great part one of convenience; thus, the distinction between incisors and grinding teeth is anatomical, that between molars and premolars refers to the history of these teeth; the connection between the teeth and the subjacent bones is a secondary matter; there is often little to differentiate canine from premolar. Moreover, the teeth of the lower jaw, which is a single bone on each side, cannot be so certainly classified as those of the upper jaw.

No part of a Vertebrate is more distinctive than the skull, and no mammalian characteristic is more useful in diagnosis than the dentition. It is convenient, therefore, to have some notation expressing the nature of the dentition. Thus we use "dental formulæ," in which the incisors, canines, premolars, and molars are enumerated in order, and in which the teeth of the upper jaw are ranked above the analogous teeth of the

lower jaw. The typical mammalian dentition already referred to may be expressed as follows :—

$$\text{Incisors } \frac{3-3}{3-3}, \text{ canines } \frac{1-1}{1-1}, \text{ premolars } \frac{4-4}{4-4}, \text{ molars } \frac{3-3}{3-3} = \frac{11-11}{11-11} = \text{total } 44.$$

or, using initial letters :—

$$\text{i. } \frac{3-3}{3-3}, \text{ c. } \frac{1-1}{1-1}, \text{ pm. } \frac{4-4}{4-4}, \text{ m. } \frac{3-3}{3-3} = 44.$$

or, recognising that the right and left side are almost invariably identical, and omitting the initial letters :— $\frac{3143}{3143}$.

We may cite the formulæ for the permanent teeth of some representative mammals :—

Opossum $\frac{5134}{4134}$, Thylacine $\frac{4134}{3134}$, Kangaroo $\frac{3024}{1024}$, Wombat $\frac{1014}{1014}$, Pig $\frac{3143}{3143}$, Camel $\frac{1133}{3123}$,

Sheep $\frac{0033}{3133}$, Horse $\frac{3143}{3143}$, Rabbit $\frac{2033}{1023}$, Cat $\frac{3131}{3121}$, Dog $\frac{3142}{3143}$, Bear $\frac{3142}{3143}$, Seal $\frac{3141}{2141}$,

Hedgehog $\frac{3133}{2123}$, Marmoset $\frac{2132}{2132}$, New World Monkey $\frac{2133}{2133}$, Old World Monkey $\frac{2123}{2123}$

Man $\frac{2123}{2123}$,

It is more interesting, however, to try to associate different kinds of dentition with different kinds of diet. Thus, dolphins, which feed on fish and swallow them whole, have numerous, almost uniform, sharp, recurved, conical teeth, well-suited to take a firm grasp of the slippery and struggling booty. To a slight extent the same piscivorous dentition may be seen in seals. In the more strictly carnivorous mammals, the incisors are small; the canines are long and sharp, piercing the prey with a deathful grip, while the back teeth have more or less knife-like edges which sever flesh and bone. In typical insectivorous mammals the upper and lower incisors meet precisely, "so as readily to secure small active prey, quick to elude capture but powerless to resist when once seized," while the crowns of the molars bear many sharp points. Herbivorous mammals have front teeth suited for cropping the herbage or gnawing parts of plants, the canines are small or absent, the molars have broad grinding crowns with transverse ridges. In omnivorous mammals, the incisors are suited for cutting, the canines are often formidable weapons in the male sex, the molars have crowns raised into rounded tubercles.

It is likely that the most primitive type of mammalian tooth was a simple cone, such as may be seen in toothed whales. In some of the extinct mammals, *e.g.*, *Triconodon*, the tooth is a main cone with two

lateral cusps, and this type leads to what is called the tritubercular tooth, in which the crown bears three cusps disposed in a triangle. From this tritubercular type most of the more complex forms of teeth may be derived.

Development and Placentation.—The ova of placental mammals are small, even those of the Whales are "no larger than fern-seed." They are formed from germinal epithelium, the cells of which grow inwards in clustered masses into the connective tissue or stroma of the ovary. In each cluster one cell predominates over its neighbours; it becomes an ovum; the others invest and nourish it, and are called follicle-cells.

In the middle of each clump or Graafian follicle, a cavity is formed containing fluid, and into this cavity the follicle cells immediately surrounding the ovum project as what is called the discus proligerus.

When mature the ovum protrudes on the surface of the ovary, and is liberated by the bursting of the Graafian follicle. Some blood, which fills up the empty follicle, degenerates into what is called the corpus luteum.

The spermatozoa are formed from germinal epithelium in the testes. The primitive male-cells or spermatogonia give rise by division to daughter-cells or spermatocytes, which with or without further division form spermatozoa.

The homologue of the ovum is the spermatogonium or mother-sperm-cell, but the spermatozoon which results from the division of the mother-cell is the physiological equivalent of the ovum.

No one has succeeded in observing any extrusion of polar bodies in the maturation of the mammalian ovum, but it is not unlikely that analogous processes occur at an early stage.

The ovum having burst from the ovary is immediately caught by the fimbriated mouth of the fallopian tube and begins to pass down the oviduct. There it is met by ascending spermatozoa, received by the female as the result of sexual union, and is fertilised. One of the spermatozoa enters the ovum, and sperm-nucleus unites with ovum-nucleus in an intimate and orderly manner. It is interesting to remember that it was only in 1843 that the union of spermatozoon and ovum was for the first time detected by Martin Barry, and in the case of the rabbit.

The Connection between Embryo and Mother.—(*a*) The lowest Mammals, the Duckmole (*Ornithorhynchus*) and the Porcupine Ant-Eater (*Echidna*) resemble Birds and most Reptiles in bringing forth their young as eggs, *i.e.*, in being oviparous. The eggs are large, with a considerable quantity of yolk, and after fertilisation divide partially, *i.e.*, exhibit meroblastic segmentation like the eggs of Birds and Reptiles. The tunic formed round about them in the Graafian follicles of the ovary consists as in Birds and Reptiles of a single layer of cells. As they develop they are unattached to the walls of the oviducts. They are laid in a nest by the Duckmole; in the Echidna they are hatched in a slight, periodically developed, external pouch.

(*b*) In the Marsupials, the connection between mother and offspring has become closer. The embryo is born alive, though prematurely, after a short uterine life, during which, however, it is either not vitally attached at all to the uterus, or only to a slight degree by villi from the yolk-sac. In the opossum, it lies surrounded by a quantity of nutritive albuminoid material. Here it may be recalled that in two Elasmobranch fishes and in two lizards, there is a connection between the yolk-sac of the embryo and the wall of the oviduct.

(*c*) In all the other Mammals, the maternal sacrifice prior to birth is greater, for a close connection is established between the embryo and the wall of the uterus, by means of a special adaptation—the placenta. This, in rough physiological language, is a double vascular sponge, partly embryonic, partly maternal, by means of which the blood of the mother nourishes and purifies that of the embryo.

As many of the most fundamental structural and functional problems in connection with placentation are still being investigated, it is impossible to discuss even the leading questions with definiteness and certainty. The authority here followed is Hubrecht, who has recently investigated in great detail the placentation of the hedgehog, which is at once a simple and a central type.

First, then, let us seek to define the embryonic and maternal structures which are associated with placentation. (1) At a very early stage, the divided ovum of the hedgehog consists of a sac of outer-layer, epiblastic or ectodermic

cells enclosing another aggregate of elements—the future inner layer, endoderm or hypoblast. (2) The epiblast divides into an embryonic disc which will form the epidermis, nervous system, etc., of the embryo, and an external layer, the wall of the embryonic sac or blastocyst, with which the disc retains a slight connection until the protective amnion is formed. In the outer epiblastic wall lacunæ develop, which are bathed by the maternal blood, and the pillars of tissue between the lacunæ grow out into villi, which aid in this earliest connection between mother and offspring. Long before any vascular area or fœtal placenta is developed, the outer epiblastic wall has the above nutritive function, and well deserves its name of trophoblast. (3) The hypoblast or inner mass, which is at first a solid aggregate of cells, becomes a sac, just as a morula may become a blastosphere. The upper part of this sac forms the lining of the incipient gut, while the lower portion, following the contour of the blastocyst wall, becomes the yolkless yolk-sac or umbilical vesicle. Its connection with the upper part is narrowed into a canal—the vitelline duct, which is part of the "umbilical cord," entering the embryo at the future navel. (4) Between the epiblast and the hypoblast of the embryo, the mesoblast develops, splitting into an outer, parietal, or somatic, and an inner, visceral, or splanchnic layer. The cavity between these is the incipient body-cavity. A double fold of somatic mesoblast, carrying with it a single sheet of epiblast, rises up round about the embryo, arching over it to form the amnion. Over the embryo the folds of amnion meet in a cupola, and the inner layers of the double fold unite to form the "amnion proper," while the outer layers also unite to form a layer lying internally to the epiblastic blastocyst-wall, — and termed by Sir William Turner the subzonal membrane. The folds of amnion are continued, as the diagram shows, ventrally as well as dorsally, so that the subzonal membrane surrounds the embryo beneath the blastocyst wall, while a splanchnic layer of mesoblast grows round about the hypoblastic yolk-sac. The space between the two layers of mesoblast, which are shortly termed somatopleure and splanchnopleure, is obviously continuous with the body-cavity of the embryo. The epiblastic outer wall or trophoblast, and the meso-

blastic subzonal membrane, are included in Hubrecht's term—diplotrophoblast. (5) From the hind-wall of the gut there grows out a hypoblastic sac, the allantois, insinuating itself and spreading out in the space between the two layers of mesoblast. As an outgrowth of the gut, homologous with the bladder of the frog, the allantois is of course lined by hypoblast or endoderm, but it is sheathed externally by a layer of mesoblast, which it bears with it as it grows. In all placental mammals the allantois, which becomes richly vascular, unites with the subzonal membrane, and therefore with the external epiblast as well, to form the fœtal part of the placenta, from which vascular processes or villi grow out and fit into corresponding depressions or crypts on the wall of the uterus. [To the mesoblastic wall of the allantois, plus the subzonal membrane, the term "chorion" is sometimes applied, but as the word has been used in many different senses, its abandonment, except perhaps in human embryology, is almost imperative.] The complex union of allantois with diplotrophoblast, Hubrecht calls the allantoidean trophoblast. (6) But in the hedgehog, rabbit, and some other types, there is a mode of embryonic nutrition between that attained by the epiblastic trophoblast and that effected by the final placenta. The wall of the yolk-sac, hypoblastic internally, mesoblastic externally, unites with the subzonal membrane, and becomes the seat of villous processes, which through the external epiblast are connected with the uterine wall. Thus is formed what Hubrecht calls an omphaloidean trophoblast. Neither omphaloidean nor allantoic villi ever directly interlock with maternal tissue, but always through the agency of the external epiblastic trophoblast.

(7.) It is now necessary to consider the maternal tissue. The embryo lay at first in a groove of the uterine wall, moored by the preliminary blastocyst villi, which are as it were pathfinders for those subsequently developed from yolk-sac and allantoic regions. At the point of attachment, the mucous lining of the uterus ceases to be glandular, and becomes much more vascular. As the embryo becomes fixed, the blastocyst almost eating its way in, the outer epithelium degenerates and disappears; below this the outer

layer of the mucous membrane becomes spongy and exhibits unique blood-spaces, forming what Hubrecht calls the trophospongia; below this there is the vascular and vitally active remainder of the mucosa, less modified than the above mentioned sponge; below this again, there are the muscular and other elements of the uterine wall, with which we are not now concerned. The most important fact to emphasize is, that the maternal blood in the spaces of the spongy outer layer of the mucous membrane directly bathes the fœtal tissue represented by the trophoblast. By the activity of the trophoblast cells, the nutritive and respiratory advantages of the maternal blood are secured for the villi of the allantois and yolk-sac. It ought also to be mentioned that, mainly by a folding of the uterine wall, the hedgehog embryo is virtually enclosed in a maternal sheath, homologous with a fold called the decidua reflexa in human embryology, and analogous with a similar capsule in the rabbit.

To sum up:—

(1) At an early stage, a wall of epiblast encloses an aggregate of hypoblast.

(2) The epiblast divides into an embryonic disc and an outer blastocyst wall, with fixing and nutritive functions,—the trophoblast.

(3) The hypoblast becomes a sac, of which the upper portion lines the gut, while the lower part forms the yolk-sac.

(4) The mesoblast divides into somatic and splanchnic layers; a double fold of the somatic layer (along with a slight sheet of epiblast) forms the amnion, of which the outer limbs unite as the subzonal membrane, and form along with the external epiblast—the diplotrophoblast. The splanchnic layer of the mesoblast is continued round the yolk-sac.

(5) The allantois grows out from the hind region of the gut, being lined internally by hypoblast, externally by splanchnic mesoblast. The allantois plus the diplotrophoblast always forms the true placenta.

(6) Part of the yolk-sac wall, uniting with the diplotrophoblast, also forms an efficient but temporary placenta.

DIAGRAM XXXI.

DEVELOPMENT OF MAMMALS.

The lowest figure (after Waldeyer) shows an ovum, surrounded by a porous membrane, the zona radiata, outside which are a few follicular cells (*f.c.*). The nucleus (*n.*) or germinal vesicle, and the nucleolus or germinal spot (*g.s.*) are also shown.

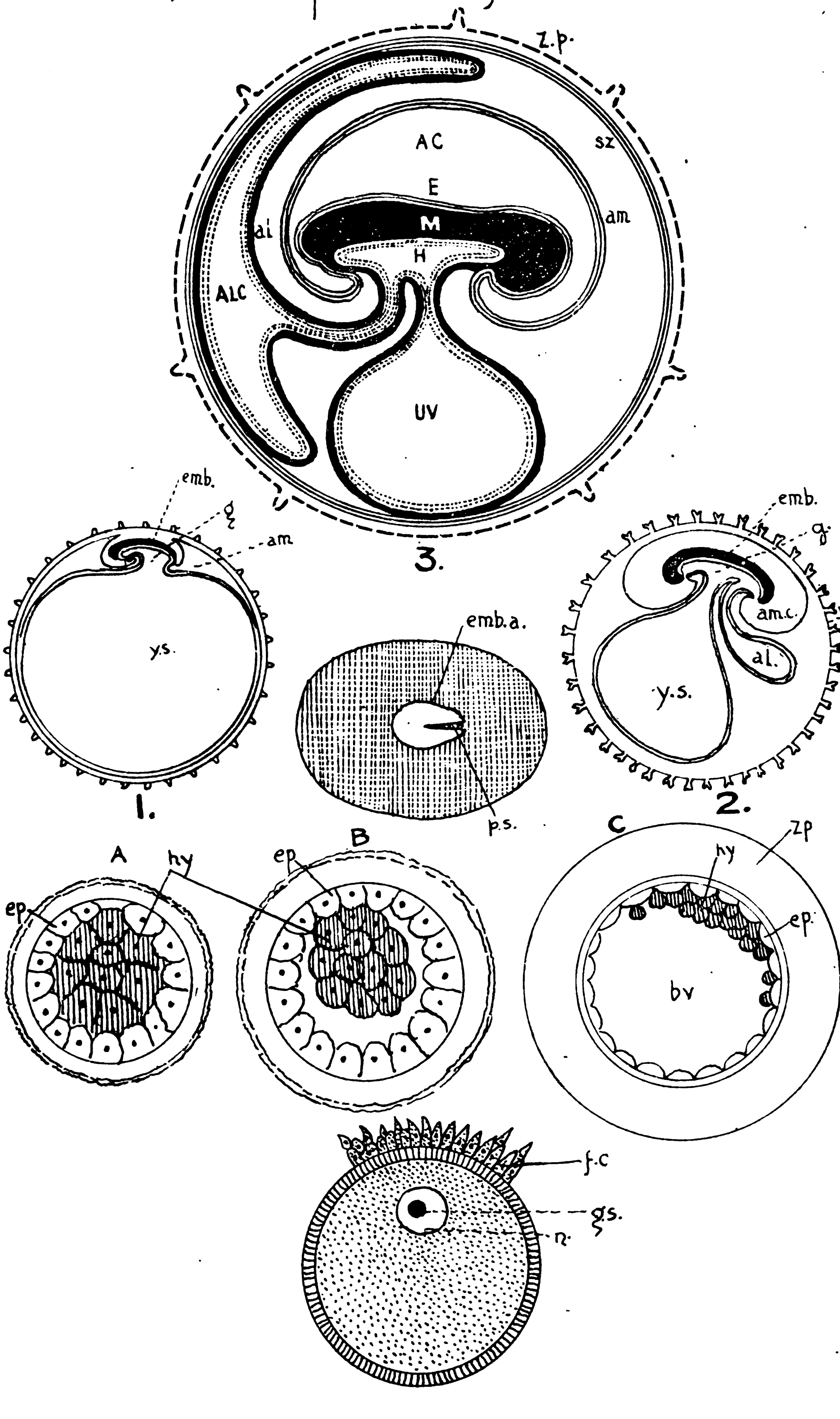
A. B. and C. (after van Beneden) show the segmentation of the ovum. Externally is an egg-envelope, between this and the ovum is a clear mucous zona pellucida (*z.p.*). The cells of the epiblast (*ep.*) are light, those of the hypoblast (*hy.*) are darkly shaded.

In the middle of the page is a surface view of the embryonic sac. The clear region in the centre (*emb. a.*) is the embryonic area, with a hint of the primitive streak (*p.s.*). The dark area round about is part of the blastocyst.

Figs 1 and 2 (after Kölliker) show the development of the fœtal membranes:—*emb.* the embryo; *g.* the gut of the embryo; *y.s.* the yolk-sac; *am.* the amniotic fold; *am. c.* the amniotic cavity bounded by the amnion proper; *al.* the allantois growing out from the gut. Externally are the preliminary villi of the trophoblast.

Fig. 3 (after Turner) shows the relations of the fœtal membranes:—*E*, the epiblast of the embryo; *M*, the mesoblast; *H*, the hypoblast lining the gut; *UV*, the umbilical vesicle or yolk-sac; *AC*, the amniotic cavity bounded by the amnion proper (*am.*); *ALC*, the cavity of the allantois (*al.*); *s.z.* the subzonal membrane or outer limb of the amniotic fold; *z.p.* may represent the external epiblast or trophoblast with its preliminary villi; where the yolk-sac unites with the subzonal membrane a yolk-sac placenta may be developed; where the allantois unites with the subzonal membrane the final placenta is formed.

Development of Mammal.



(7) At the area of fixing, the uterine epithelium degenerates, the glands disappear, vascularity increases. The outer part of the modified mucous membrane (or decidua) becomes a spongy tissue, with spaces filled with maternal blood. This maternal blood bathes the trophoblast, which is intermediate between it and the placental villi.

The three modes of embryonic nutrition are as follows:—

(*a*) At first the maternal blood bathes the lacunæ in the epiblastic outer wall—the trophoblast with its preliminary path-finding villi.

(*b*) An efficient yolk-sac placenta functions for a while, but decreases and shrivels as the final allantoidean placenta develops. The maternal blood in the spaces of the outer layer of the mucous layer of the uterus bathes the trophoblast. Thus it comes into indirect connection with the vascular villi from the region where the yolk-sac wall unites with the diplotrophoblast. This yolk-sac placenta is found in Insectivora, Chiroptera, and Rodents.

(*c*) The final placenta is allantoidean, it replaces the yolk-sac placenta if there be one. In Insectivora, Chiroptera, and Rodentia, and probably in other cases, the trophoblast is always intermediate between the maternal blood and the villi, and is the only intervening tissue.

THE CUSTOMARY CLASSIFICATION OF PLACENTATION (WHICH WILL PROBABLY BE SOMEWHAT ALTERED IN THE NEXT FEW YEARS) IS AS FOLLOWS:—

Caducous or Deciduate. (Vascular parts of maternal placenta come away at birth).	*Meta-Discoidal.*—Villi at first scattered are restricted to a disc. The maternal mucous membrane forms a capsule around the embryo (decidua reflexa, also seen in hedgehog).	*Homo* and Monkeys.
	Discoidal.—Villi on a circular cake-like disc.	Rodentia. Insectivora and Chiroptera. Most Edentata.
	Zonary.—Villi on a partial or complete girdle round the embryo.	Carnivora. Elephants and Hyrax. *Orycteropus* and *Dasypus* among Edentata. Dugong (in whole or in great part non-deciduate).
Non-Caducous or Indeciduate. (Maternal part of placenta does not come away at birth).	*Cotyledonary.*—Villi in patches.	Ruminants.
	Diffuse.—Scattered Villi.	Lemurs. Most Ungulates except Ruminants. Cetacea.. *Manis* among Edentata.

Again the anatomical relations may be summed up in tabular form :—

EPIBLAST.	MESOBLAST.		HYPOBLAST.	
(1) Embryonic (formative).	(1) Embryonic (formative).		(1) Embryonic (formative).	
(2) Extra-embryonic (attaching, protective, nutritive).	(2) Extra-embryonic. Somatic and	Splanchnic.	(2) Extra-embryonic lining (allantois and yolk-sac.)	
(*a*) Thin sheet along with amnion.	(a^1) Amnion proper.			
(*b*) Outer wall of blastocyst, the "trophoblast."	(b^1) Sub-zonal membrane.	(b^2) Outer lining of allantois.	(b^3) Inner lining of allantois.	*Allantoic placenta.*
Diplotrophoblast.		(c^2) Outer layer of yolk-sac	(c^3) Inner lining of yolk-sac.	*Yolk-sac placenta.*

While Sir William Turner, "the grand master of placental research," in his arrangement of placentas, allots the lowest place to such diffuse forms as that of the pig, passes thence to the cotyledonary of Ruminants, thence to the zonary of Carnivores, and finally to the discoidal of monkeys and man, others maintain that the discoidal, as illustrated in the primitive Insectivora, is the most primitive type.

To avoid confusion it may be better, as Hubrecht suggests, to revert to the old terms caducous and non-caducous, instead of deciduate and indeciduate, for all placental mammals have a "decidua," or specially active region of the mucous membrane of the uterus to which the embryo is attached. Moreover, the distinction between deciduate and indeciduate is one of degree, for no sharp line can be drawn between the two types.

THE RABBIT as a type of Mammals.

The rabbit (*Lepus cuniculus*) is a familiar representative of the Rodent order, to which rats and mice, voles and beavers, lemmings and marmots also belong. Like the hare (*Lepus timidus*) and other species of the same genus, and like the Picas or tailless hares (*Lagomys*), the rabbit has two pairs of incisors in the upper jaw, instead of a single pair. Therefore the genera *Lepus* and *Lagomys* are ranked in the sub-order Duplicidentata, in contrast to all other Rodents which are included in the sub-order Simplicidentata.

With the rabbit's mode of life all are familiar. It is herbivorous, and often leaves softer food for the succulent bark of young trees; it is gregarious and a burrower; it is very prolific, often breeding four to eight times in a year. It is said to live, in normal conditions, seven or eight years. The rabbit seems to have had its original home in the western Mediterranean region, but it has spread widely throughout Europe, and is now abundant in countries, such as Scotland and Ireland, in which not many years ago it was quite rare. Introduced into Australia and New Zealand it has multiplied exceedingly, and has become a scourge. There are many varieties of rabbit, some in insulated regions illustrating the efficacy of segregation in fostering divergent types. Thus,

according to Darwin, the rabbits introduced early in the fifteenth century into Porto Santo, an island near Madeira, are now represented by a dwarf race of about half the normal size, and these are said to be incapable of breeding with the ordinary forms. But the varieties with which we are familiar in the breeds of tame rabbits, illustrate variation under domestication and the efficacy of artificial selection.

External appearance.—The head bears long external ears which are freely movable. The black patch at the tip of the ears in the hare is either absent or very small in the wild rabbit. This external ear is characteristic of most Mammals, and seems to collect the sound like an ear-trumpet. In the rabbit it is longitudinally folded, thin and soft towards its tip, firm and cartilaginous at its base. The large eyes have eyelids with few eyelashes, and a third eyelid or nictitating membrane—a white fold of skin—lies in the anterior corner. This third eyelid, the occurrence of which we have already noticed in Reptiles and Birds, is present in most Mammals, and is of use in cleaning the cornea. It is absent in Cetaceans, where the front of the eye is bathed by the water, and it is more or less rudimentary in man and monkeys where the habitual winking of the upper eyelid makes a nictitating membrane superfluous. The nostrils are two slits at the end of the snout, and are connected with the mouth by a "hare-lip" cleft in the middle of the upper lip. In front of the mouth are seen the chisel-edged incisors, a pair on the mandibles, and two pairs on the premaxillæ,—the smaller pair lying behind the larger pair and concealed by them. Through the toothless gap or diastema between the front and back teeth, the hairy skin of the lips projects into the mouth. On the sides of the snout, and about the eyes, there are tactile hairs or vibrissæ.

The plump trunk is separated from the head by a short neck. The tail is very short, but in the scampering wild rabbit it is conspicuous as a white tuft, which some naturalists interpret as a directive signal. Beneath the base of the tail the food-canal ends, and beside the anus are the openings of perineal glands, the secretion of which gives the rabbit a characteristic odour. In front of the anus is the urino-genital aperture,—in the male at the end of an ensheathed penis, in the female a slit or vulva, with an

anterior process or clitoris—the homologue of the penis. Beside the penis in the male lie the scrotal sacs, into which the testes descend when the rabbit becomes sexually mature. Along the ventral surface of the thorax and abdomen in the female there are four or five pairs of small teats or mammæ.

The limbs have clawed digits, five on the fore-feet, four on the hind-feet, and they are very hairy.

Skin and Muscles.—The skin is thickly covered with hair, and has the usual sebaceous and sudorific glands, besides special glands, such as the perineal glands beside the anus, the glands of the eyelids, the lachrymal glands, and the mammary glands developed in the females. Between the skin and the subjacent muscles there is a layer of fatty tissue, known as the panniculus adiposus; it is present in all Mammals except the common hare, and forms the important blubber of whales and seals. Beneath the skin there is a thin sheet of muscle called the panniculus carnosus, and when this is removed with the skin, many of the muscles of head and neck, limbs and trunk are disclosed. The student who wishes to study these, and to compare them with their homologues in man, will find minute practical directions in Parker's *Zootomy*.

The Skeleton.—The bones, like those of other Vertebrates, are developed either as replacements of pre-existent cartilages, or independent of any such preformations, but in all cases through the agency of active periosteal membranes. By themselves, however, must be ranked little sesamoid bones, which are developed within tendons and near joints, notably for instance, the patella or knee-pan. There is no bony exoskeleton in any mammals except the armadillos, unless we rank the teeth, which develop in connection with the skin of the jaws, as in a sense exoskeletal. The vertebral centra of Mammals, except in Monotremes and Sirenians, have distinct terminal ossifications, known as epiphyses, and the same distinctness of ossification is seen in many of the larger bones.

The vertebræ may be grouped as cervical (seven in number), thoracic (with ribs), lumbar (without ribs), sacral (fused to support the pelvis), and caudal. The faces of the centra are more or less flat, and between adjacent vertebræ there are inter-vertebral discs of fibro-cartilage.

The first vertebra or atlas is ring-like, its neural canal being very large, its centrum unrepresented unless by the odontoid process which fuses to the second vertebra. The ring is divided transversely by a ligament, through the upper part the spinal cord passes, into the lower the odontoid process projects. The transverse processes are very broad; the articular surfaces for the two condyles of the skull are large and deep.

The second vertebra or axis has a broad flat centrum produced in front in the odontoid process. The neural spine forms a prominent crest, the transverse processes are small, the anterior articular surfaces are large.

A typical lumbar vertebra will show the centrum and its epiphyses, the neural arch and neural spine, the transverse processes, the anterior and posterior articular processes or zygapophyses, the median ventral hypapophysis, the small anapophyses from the neural arch below the posterior zygapophyses, below the anapophyses the posterior intervertebral notches—passages through which the spinal nerves pass out, and anteriorly a similar pair of notches. There are twelve or thirteen pairs of ribs which support the wall of the thorax, and aid in the mechanism of respiration. The first seven pairs articulate with the breast-bone, the eighth and ninth are connected to the ribs in front, the others are free. Any one of the first seven or more typical ribs consists of two parts, a vertebral portion articulating with a vertebra, an imperfectly ossified sternal portion connecting the end of the vertebral portion with the sternum. Each of the first nine ribs has a double head—the capitulum articulating with the centrum of the corresponding vertebra, and partly with that of the one in front, the tubercle articulating with the transverse process of the corresponding vertebra. The posterior ribs have no tubercles, and the capitular articulations are restricted to the corresponding vertebræ.

The sternum is a narrow jointed plate, with a large keeled præsternum or manubrium, then five segments composing the mesosternum, then a posterior xiphisternum ending in cartilage.

The Skull.—The skull consists, as in all the higher Vertebrates, of two sets of bones,—cartilage-bones preformed in the cartilage of the original gristly brain-box and its asso-

ciated arches, membrane-bones developing in the investing skin and not preformed in cartilage. In the following account, the names of the membrane-bones are printed in italics.

We have already noticed the chief characteristics of the mammalian skull, such as the usual persistence of sutures, the two condyles, the bony palate, the fusion of the periotic bones, the articulation of the mandible with the squamosal, the fusion of the parts of each ramus of the mandible into a single bone in the adult, and the three ossicles of the internal ear.

In studying the skull it is convenient to consider the bones in groups. Along the roof of the skull from behind forwards lie the supra-occipital, the *parietals*, the *frontals*, and the *nasals*. Between the supra-occipital and the *parietals* there is a small *interparietal*.

On the posterior surface of the skull, the foramen magnum, through which the spinal cord issues from the cranial cavity, is bounded by the basi-occipital beneath, the ex-occipitals on the sides, the supra-occipital above. The ex-occipitals form most of the occipital condyles, but the basi-occipital contributes a small part. In many mammals the ex-occipitals alone form the condyles. From each ex-occipital a par-occipital process descends and is applied to the tympanic bulla—a dilatation at the base of the tympanic bone which protects the external auditory tube.

On the very front of the skull are the *premaxillæ* beariug the incisor teeth. Behind each *premaxilla* is a *maxilla*, bearing the premolars and molars, behind this, along the zygomatic or temporal arch projecting beneath the orbit is the *jugal* or malar which unites posteriorly with the *squamosal*. This zygomatic arch bridges over the deep temporal fossa behind the orbit, and serves for the insertion of muscles, and its "squamoso-maxillary" structure occurs outside of Mammalia in the Anomodont reptiles only. The *squamosals* form a great part of the posterior side-walls of the skull, and articulate with the *parietals*, *frontals*, orbitosphenoids, and alisphenoids. At the posterior end of the zygomatic arch is the longitudinally elongated glenoid cavity in which the mandible moves backwards and forwards.

In connection with the floor of the skull and the roof of the mouth, there lie from behind forwards the following components:—the median basi-occipital; the median basisphenoid which lodges the pituitary body in a dorsal depression called the sella turcica; the paired alisphenoids fused to the sides of the basisphenoid; the median presphenoid which forms the lower margin of the optic foramen between the two orbits; the paired orbitosphenoids, fused to the presphenoid, sutured to the alisphenoids and squamosals, and surrounding the optic foramen; the vertical *pterygoids* attached at the junction of basisphenoid and alisphenoids; the nearly vertical *palatines*, united above to the presphenoid and behind to the *pterygoids* and alisphenoids, separating the posterior nasal passages from the orbits, and uniting in front to form the posterior part

DIAGRAM XXXII.

Mammalian Structures.

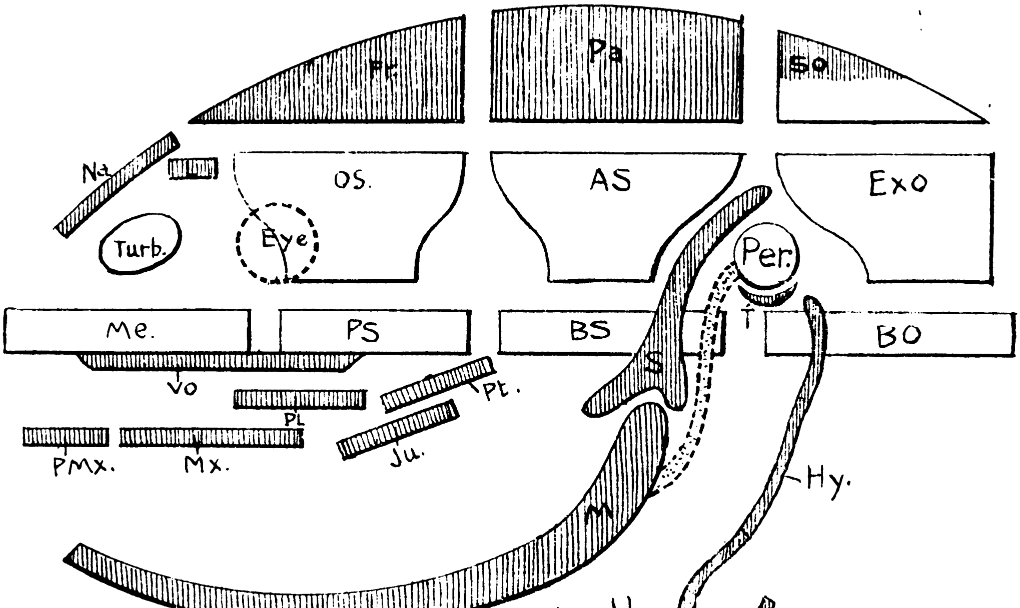
The diagram of the skull (after Flower) shows the bones, the membrane-bones shaded, the cartilage-bones light; *S.o.*, supra-occipital; *Pa*, parietal; *Fr*, frontal; *Na*, nasal; *L*, lachrymal; *Ex.o*, ex-occipital; *As*, alisphenoid; *Os*, orbitosphenoid; *Turb.*, turbinal; *Me*, mesethmoid; *Ps*, presphenoid; *Bs*, basisphenoid; *B.o*, basi-occipital; *Vo*, vomer, *Pmx*, premaxilla; *Mx*, maxilla; *Ju*, jugal; *Pt*, pterygoid; *Pl*, palatine; *M*, mandible; *S*, squamosal; *Per*, periotic; *T*, tympanic; *Hy*, hyoid.

The diagram of the brain (after Wiedersheim), shows the fore-brain (*F.B.*), the corpus callosum (*C.C.*), the fornix (*F.*), the pineal gland (*P.g.*), the optic thalami (*Th.*); the anterior commissure (*C.*), the median commissure (*C.*); the posterior commissure (*C.*); the optic lobes (*Opt. l.*); the cerebellum (*Cerebell.*); the medulla oblongata (*Med.*), the foramen of Munro (*F.M.*); the infundibulum (*Inf.*); the pituitary body (*Pit.*); the optic nerve (*II.*); the olfactory nerve (*I.*).

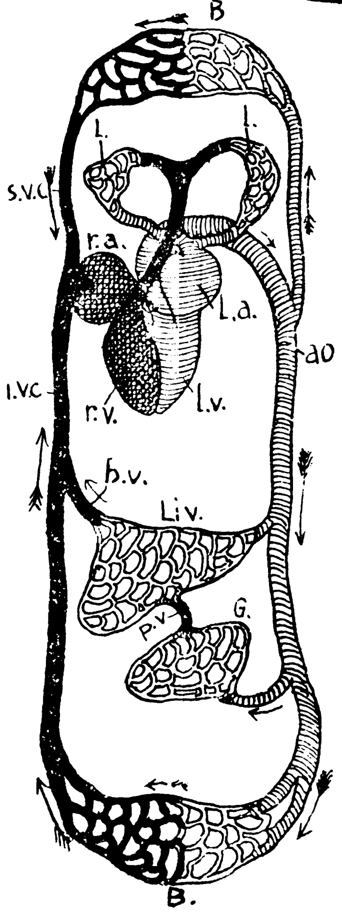
The diagram of the circulation (from Leunis) shows—the right auricle (*r.a.*); the right ventricle (*r.v.*); the pulmonary arteries and veins to and from the lungs (*l.*); the left auricle (*l.a.*); the left ventricle (*l.v.*); the aorta (*ao.*) to the anterior and posterior parts of the body (*B.*); the arteries to the gut (*G.*) and the liver (*Liv.*); the portal veins (*p.v.*) from the gut to the liver; the hepatic veins (*h.v.*) from the liver to the inferior vena cava (*i.v.c.*); the superior vena cava (*s.v.c.*). The venous system is darkly shaded.

The development of a hair (after Hertwig) shows—the dermis (*Derm*) and its papilla; the stratum Malpighii (*s.m.*) of the epidermis; the stratum corneum (*s.c.*) of the epidermis; the formation of the hair-follicle; the associated sebaceous glands (*g.*); the developing hair (*h.*).

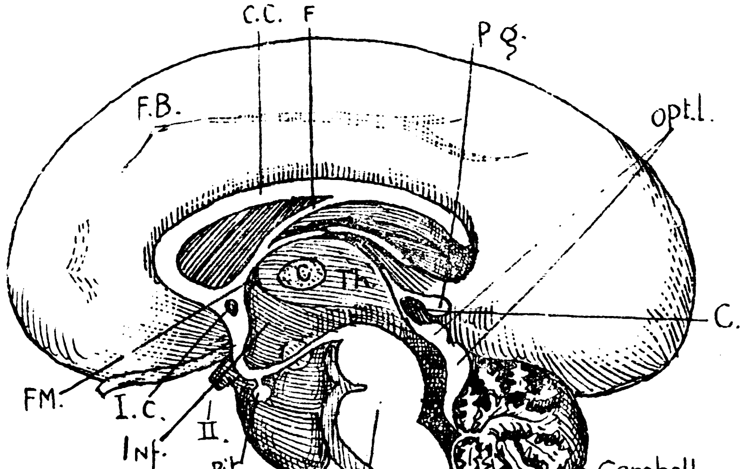
Mammals.



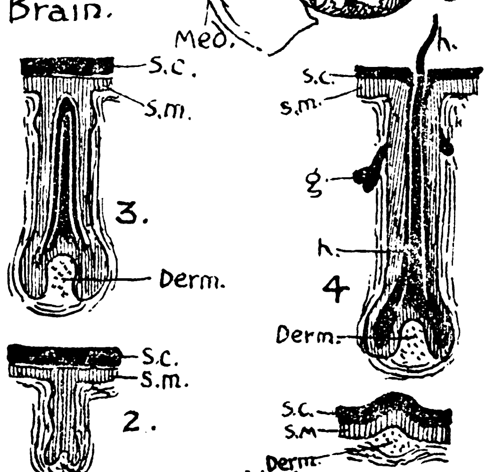
Skull.



Circ.



Brain.



Hair

of the bony palate; the median vertical mesethmoid cartilage extending in front of the presphenoid, separating the two nasal cavities, posteriorly ossified and expanded into the sieve-like cribriform plates through the apertures of which the branches of the olfactory nerves pass to tbe nose; the paired *vomers* along the ventral edge of the mesethmoid; and lastly, the anterior bony palate formed from inward extensions of *maxillæ* and *premaxillæ*.

Wedged in between the occipitals, the *squamosals*, and the bones of the basisphenoid region, there is on each side a periotic bone surrounding the internal ear. It ossifies from three centres in the cartilaginous auditory capsule, and consists of a dense petrous portion enclosing the essential part of the ear and a more external porous mastoid portion which is produced downwards into a mastoid process in front of the paroccipital process. From each periotic a *tympanic* bone extends outwards, swollen basally into a tympanic bulla in which the tympanum or drum of the ear is stretched, and continued around the external auditory meatus. From an aperture between the tympanic and the periotic the Eustachian tube passes to the pharynx. Stretching from the tympanum to the fenestra ovalis of the inner ear is the chain of minute ear-ossicles, the three links of which—malleus, incus, and stapes—possibly correspond respectively to the articular, the quadrate, and hyo-mandibular or columella of most other Vertebrates.

The orbits are bounded anteriorly by the *lachrymals* and the *maxillæ*, and above by the *frontals*. The interorbital septum is formed above and behind by the orbitosphenoids, below by the presphenoid.

Associated with the olfactory chambers, are the *nasals* above, the *vomers* beneath, the mesethmoid in the median line, while internally there are several thin scroll-like turbinal bones.

The lower jaw or *mandible* consists in adult life of a single bone or ramus on each side, but this is formed around Meckel's cartilage from several centres of ossification. Its condyle works in the glenoid cavity of the *squamosal*.

The hyoid lies between the rami of the mandible, in the back of the mouth, and consists of a median "body," and two pairs of horns or cornua extending backwards.

The Appendicular Skeleton consists of the bones of the limbs and the girdles which support these.

The pectoral girdle, which supports the fore-limbs and is itself attached by muscles and ligaments to the vertebral column, virtually consists of one bone—the scapula—on each side. For in the rabbit, as in all Mammals except Monotremes, the coracoid, though a distinct ossification, forms only a small process projecting from the anterior margin of the glenoid cavity in which the head of the humerus works. The clavicle is also much reduced in the rabbit, being only about an inch in length and very slender. It is a membrane-bone, and lies in the ligament between the

scapula and the sternum. The triangular scapula has a prominent external ridge or spine, continued ventrally into an acromion with a long metacromion process. The scapula is usually strong, and the clavicle is usually present in mammals which grasp or climb or burrow.

The fore-limb consists of an upper arm or humerus, a fore-arm of two bones—the radius and the ulna, a wrist or carpus, five palm-bones or metacarpals, and five digits with joints or phalanges.

The head of the humerus works in the glenoid cavity formed by the scapula and the coracoid process.

When the arm of a mammal is directed outwards at right angles to the body, with the palm vertical and the thumb uppermost, the thumb and the radius are in a preaxial position, the little finger and the ulna are in a postaxial position. But in the normal position of the limb in most mammals, the radius and the ulna cross one another in the fore-arm, so that the preaxial radius is external at the upper end, internal at the lower end.

The typical mammalian wrist or carpus consists of two rows of bones, with a central bone between the two rows. In the rabbit all the bones —nine in number—are present.

Ulnare or Cuneiform. Intermedium or Lunar. Radiale or Scaphoid.

Centrale.

Carpale 5 and 4 or Unciform. Carpale 3 or Magnum. Carpale 2 or Trapezoid. Carpale 1 or Trapezium.

In Mammals the fourth and fifth carpals are always fused; the centrale is often absent. In the tendons of the flexor muscles there are often two sesamoid bones, of which the ulnar is called the pisiform.

In the rabbit there are five metacarpal bones and five digits, each with three phalanges except the thumb or pollex which has but two.

The pelvic girdle is articulated to the backbone, and bears externally a cup-like socket or acetabulum in which the head of the thigh bone works. Each half of the girdle—forming what is called the innominate bone—really consists of three bones which meet in the acetabulum. The dorsal bone or ilium, which corresponds to the scapula, articulates with the sacral vertebræ; the pubis—the anterior of the two lower bones—unites with its fellow on the opposite side in the pubic symphysis; the two ischia, which correspond to the coracoids, extend backwards, separated from the pubes by the large obturator foramen, and expand into posterior tuberosities. The ischia of mammals may touch one another

ventrally, but do not fuse in a symphysis; the pubic symphysis is almost invariably present. Only in Cetacea and Sirenia is the pelvis markedly rudimentary.

The hind-leg consists of a thigh or femur, a lower leg with two bones—the tibia and the fibula, an ankle or tarsus, the sole bones or metatarsals, the toes with several joints or phalanges.

The head of the femur works in the acetabulum of the pelvis. Near the head are several processes or trochanters serving for the insertion of muscles; in the rabbit there are three, the great trochanter, the lesser trochanter, and the third trochanter.

In front of the knee there is a sesamoid bone—the knee-pan or patella, and posteriorly there are smaller fabellæ.

In the lower leg, the tibia, which corresponds to the radius, is preaxial and in the normal position interior; the fibula which corresponds to the ulna, is postaxial and in the normal position exterior. In the rabbit the fibula is slender, and is fused distally with the tibia.

In the mammalian tarsus there are two rows of bones and a central bone interposed between the two rows on the inner or tibial side.

Calcaneum or Fibulare.		Astralagus (=Intermedium and Tibiale).	
		Centrale or Navicular.	
Tarsale 5 and 4 =Cuboid.	Tarsale 3 or External Cuneiform.	Tarsale 2 or Middle Cuneiform.	Tarsale 1 or Internal Cuneiform.

In the rabbit the first tarsal and the corresponding toe or hallux are wanting. There are thus only four metatarsals and digits. Each digit has four phalanges.

Nervous System.—The brain has the usual five parts—cerebral hemispheres, optic thalami, optic lobes, cerebellum, and medulla oblongata, but the cerebral hemispheres cover the next two parts, and the cerebellum conceals the medulla. Of the brain-membranes, the dura mater lines the cranial cavity, projecting longitudinally between the cerebral hemispheres, and transversely between the latter and the cerebellum, while the vascular pia mater invests the brain closely. There are the usual twelve pairs of cranial nerves. The spinal cord gives off the usual spinal nerves, and there is a sympathetic system as in most other Vertebrates.

The cerebral hemispheres of the rabbit are but slightly convoluted, and they leave the cerebellum quite uncovered. They are connected transversely by a broad bridge—the corpus callosum, and beneath this

there is a longitudinal band of fibres—the fornix. The corpus callosum is readily disclosed by gently separating the hemispheres. The outer wall and floor of the anterior part of the cavity or ventricle of each hemisphere is formed by a thick mass called the corpus striatum, and the internal cavity is lessened by a prominent convex ridge called the hippocampus major. The ventricles of the cerebrum communicate with the third ventricle between the optic thalami, by a small aperture called the foramen of Munro. In front of the hemispheres two club-shaped olfactory lobes project. The thin cortical layer of the cerebrum consists of grey (ganglionic) matter, and so does the thick corpus striatum, while the central part consists of white matter (nerve-fibres).

The thalamencephalon is entirely hidden, but gives origin as usual to the dorsal epiphysis ending in a pineal body, which lies on the surface between the cerebrum and cerebellum, and to the ventral infundibulum at the end of which the pituitary body lies, lodged in a fossa of the basisphenoid. Immediately in front of the infundibulum, the optic nerves cross in a chiasma, from which optic tracts can be traced to the optic lobes. Immediately behind the infundibulum lies a rounded elevation, called the mamillary body. Anteriorly on the ventral surface of each side of the thalamencephalon, there is a rounded swelling called the corpus geniculatum. The roof of the third ventricle is formed by a thin membrane or velum with a plexus of blood-vessels. In the anterior wall of the third ventricle lies the small anterior commissure, across the third ventricle the large middle commissure runs, in the roof of the hind part of the ventricle lies a small posterior commissure.

The optic lobes are four-fold—corpora quadrigemina. They are almost quite covered by the cerebrum. Between them runs the iter connecting the third ventricle and the fourth. The floor of this passage is formed by the thick crura cerebri which connect the medulla with the cerebrum.

The cerebellum is divided into a median and two lateral lobes, and is marked by numerous folds mostly transverse. The two sides are connected ventrally by the Pons Varolii, lying across the anterior ventral surface of the medulla.

The medulla oblongata lies beneath and behind the cerebellum, and is continued into the spinal cord. The cavity of the fourth ventricle is roofed by a thin membrane or velum, above which lies the cerebellum. On the ventral surface the medulla is marked by a deep fissure, bordered by two narrow bands or ventral pyramids.

The spinal cord presents its usual appearance, with its dorsal sensory nerve-roots with ganglia, its ventral motor nerve-roots apparently without ganglia, and the spinal nerves formed from the union of these. The ganglia of the adjacent sympathetic system perhaps belong to the ventral roots of the spinal nerves.

A large number of nerves pass down the neck. Of these the following are most important :—

(1) The eleventh cranial nerve or spinal accessory, leaving the skull with the ninth and tenth, and distributed to the muscles of the neck.

(2) The twelfth cranial nerve or hypoglossal, lying at first close to the ninth, tenth, and eleventh, turning however to the muscles of the tongue.

(3) The tenth cranial nerve, the pneumogastric or vagus, lies outside the carotid artery, and gives off a superior laryngeal to the larynx with a depressor branch to the heart, an inferior or recurrent laryngeal which loops round the subclavian artery, and runs forward to the larynx, and other nerves to the heart, lungs, and gullet.
(4) The cervical part of the sympathetic, lying alongside of the trachea, with two ganglia.
(5) The great auricular, a branch of the third spinal nerve, running to the outer ear.
(6) The phrenic nerve, a branch of the fourth cervical nerve, with a branch from the fifth and sometimes from the sixth, runs along the backbone to the diaphragm.

For details as to these nerves, the student should consult the practical manuals of Marshall and Hurst and of Parker.

As to the sense-organs little need be said, for their general structure is like that of other Vertebrates, while the detailed peculiarities are beyond our present scope.

The third eyelid, present in all mammals except the Cetaceans and the Primates, is well-developed. The lachrymal gland (absent in Cetacea) lies under the upper lid, and the lids are kept moist by the secretion of Harderian and Meibomian glands. The external ear or pinna is conspicuously large. The cochlea of the inner ear is large and spirally twisted. The nostrils are externally connected with the mouth by a characteristic cleft lip. The tongue bears numerous papillæ with taste-bulbs. The long hairs or vibrissæ on the snout are tactile.

Alimentary System.—In connection with the cavity of the mouth we notice the characteristic dentition, the hairy pad of skin intruded in the gap between incisors and premolars, the long and narrow, in part bony, palate separating the nasal from the buccal cavity, the muscular tongue with its taste-papillæ, the glottis which leads into the windpipe, and the bilobed flap or epiglottis which guards the opening, the paired apertures of the Eustachian tubes opening into the posterior nasal passage, the end of this passage above the glottis, and the beginning of the pharynx. Less obvious are the organs of Jacobson, paired tubular bodies lying enclosed in cartilage in the front of the nasal chamber, and communicating on the one hand with the nostrils, and on the other hand with the mouth by two naso-palatine canals which open a little way behind the posterior incisors. Opening into the mouth and bearing the salivary juice, whose ferment alters the starchy parts of the food, are the ducts of four pairs of salivary glands. The parotid, which is largest, lies between the external ear chamber and the angle of the mandible; the infra-orbital lies below and in front of the eye; the sub-

maxillary lies between the angles of the mandible; the sub-lingual lies along the inner side of each ramus of the mandible.

The pharynx passes into the gullet, and that leads through the diaphragm to the expanded stomach, which is dilated at its upper or cardiac end, and narrows to the curved pyloric end. Partly covering the stomach is the large liver. The first portion of the intestine, which is called the duodenum, receives the bile-duct, and has the pancreas in its folds. Then follows the much coiled small intestine measuring many feet in length. The lower end of the small intestine is expanded into a sacculus rotundus. Here the large cæcum—a blind diverticulum—is given off; it ends in a finger-like vermiform appendix. Its proximal end is continuous with the colon or first part of the large intestine, the beginning of which is much sacculated. The large intestine narrows into the long rectum in which lie little fæcal pellets. On the last two inches of the rectum there are paired yellowish glands. Beside the anus are two perineal sacs of skin, into which open the ducts of the perineal glands, whose secretion has a characteristic and strong odour.

The liver is moored to the diaphragm by a fold of peritoneum—the glistening membrane which lines the abdominal cavity. In the liver there are five lobes. From these lobes the bile is collected by hepatic ducts into a common bile-duct, which is also connected to the gall-bladder by the cystic duct.

The pancreas is very diffuse, and lies like fat in the mesentery of the duodenal loop. Its secretion is gathered by several tubes into the pancreatic duct which opens into the duodenum.

The mesentery which supports the alimentary canal, is a double layer of peritoneum reflected from the dorsal abdominal wall.

Here, for convenience, we may also note, that the dark-red spleen (apparently of importance in connection with the blood), lies behind the stomach. In the mesentery, not far from the top of the right kidney, lie a pair of cœliac ganglia, which receive nerves from the thoracic sympathetic system, and give off branches to the gut.

The Vascular System.—The four-chambered heart lies in

the thoracic cavity between the lungs. It is surrounded by a thin pericardium, and immediately in front of it there lies the soft thymus, which is larger in the young than in the adult animal.

By two superior venæ cavæ, and by the inferior vena cava, the venous blood collected from the body enters the right auricle. Thence the blood passes into the right ventricle through a crescentic opening, bordered by a threefold (tricuspid) membranous valve (worked by chordæ tendineæ attached to papillary muscles projecting from the wall of the ventricle).

The right ventricle is not so muscular as the left, which it partly surrounds. By its contraction the blood is driven into the pulmonary trunk, whose orifice is guarded by three semilunar valves. During contraction, the tricuspid valves are pressed together, so that no regurgitation into the right auricle can take place.

The pulmonary trunk divides into two pulmonary arteries, which divide into capillaries on the walls of the lungs. There the red blood-corpuscles gain oxygen, and the blood is freed from much of the carbonic acid gas which it has borne away from the tissues. The purified blood returns to the heart by two pulmonary veins, which unite as they enter the left auricle.

From the left auricle, the pure blood passes into the left ventricle through a funnel-like opening, bordered by a (mitral) valve with two membranous flaps, with chordæ tendineæ and musculi papillares as on the right side, but the muscles here are larger.

The left ventricle receives the pure blood and drives it to the body. During contraction, the mitral valve is closed, so that no blood can flow back into the auricle. The blood leaves the left ventricle by an aortic trunk, whose base is guarded by three semilunar valves, just above which coronary arteries arise from the aortic trunk and supply the heart itself.

The aortic trunk bends over to the left, and passes backward under the backbone, dividing near the pelvis into two common iliac arteries, which supply the hind-legs and posterior parts. The arteries given off near the heart and in the abdominal region may be grouped as follows:—

The aortic trunk

gives off the innominate artery,

which divides into (*a*) the right subclavian, continued as the brachial to the fore-limb, but giving off the vertebral to the spinal cord and brain, and the internal mammary to the ventral wall of the thorax :

(*b*) the right carotid, running along the trachea, dividing into the right internal carotid to the brain; and the right external carotid to the head and face :

(*c*) the left carotid, with a similar course:

thereafter the aorta gives off

the left subclavian artery, with branches like the right,
the cœliac artery to the liver, stomach, and spleen,
the anterior mesenteric to the pancreas and intestine,
the renal arteries to the kidneys,
the spermatic or ovarian arteries to the reproductive organs,
the posterior mesenteric to the rectum,
the lumbar arteries to the posterior body-walls,

The aorta is continued terminally in the median sacral artery to the tail, and laterally in the common iliacs which form the femorals of the hind-legs, and give off in the abdomen several branches to the abdominal walls, the pelvic cavity, the bladder, and the uterus.

The Venous System. The two superior venæ cavæ bring blood from the head, neck, thorax, and fore-limbs. Each is formed from the union of

a subclavian from the shoulder and fore-limb,
an external jugular from the face and ear,
an internal jugular from the brain,
an anterior intercostal from the spaces between the anterior ribs,
an internal mammary from the ventral wall of the thorax ;

and the right superior vena cava also receives an azygous cardinal vein, which runs along the mid-dorsal line and collects blood from the posterior intercostal spaces.

The inferior vena cava is a large median vein lying beside the aorta beneath the backbone. Anteriorly it is embedded in the liver, and receives the hepatic veins. Thence it passes through the diaphragm into the right auricle. Posteriorly the inferior vena cava has the following components :—

internal iliacs from the back of the thighs, forming by their union the beginning of the inferior vena cava ;
femoral veins from the inner borders of the thighs, continued into external iliacs which open into the inferior vena cava ;
paired ilio-lumbars from the posterior abdominal walls ;
spermatic or ovarian veins from the reproductive organs ;
renal veins from the kidneys.

There is no renal portal system.

The food which has been digested—rendered soluble and diffusible—passes from the food-canal into the vascular system by two paths :—

(*a*) All except the fatty material is absorbed by veins from the stomach and intestine. These unite in a main trunk the portal vein. The components of the portal vein are—the lieno-gastric from the stomach (and also from the spleen), the duodenal from the duodenum (and also from the pancreas), the anterior mesenteric from the intestine, the posterior mesenteric from the rectum. The portal vein breaks up into branches into the liver, whence the modified blood passes by hepatic veins into the inferior vena cava.

(*b*) The fat passes through the intestinal villi into the lymphatic vessels, which combine to form a thoracic duct which runs forward, and opens into the left subclavian vein at its junction with the left external jugular. Here and there lie lymphatic glands.

Respiratory System.—The lungs are pink, spongy bodies, lying in the thorax, connected to the exterior by the bronchial tubes and the trachea, and to the heart by blood-vessels. The pleural membrane which invests the surface of the lungs is reflected on to them from the sides of the thoracic cavity. When the lungs expand, the pleural cavity—between the two folds of pleural membrane—is almost obliterated. The thoracic cavity is separated from the abdominal cavity by a partly muscular partition or diaphragm, which is supplied by two phrenic nerves, arising from the fourth cervical spinal nerves. By its contraction the diaphragm alters the size of the thoracic cavity, and thus shares in the mechanism of respiration. At the top of the trachea lies the complex larynx, the seat of the voice in mammals.

Anteriorly the larynx is supported on its sides and beneath by the thyroid cartilage, behind this lies the ring-like cricoid, dorsally to the cricoid are two small triangular arytenoids.

Within the larynx there are stretched membranous bands—the vocal cords. Beside the larynx is the paired thyroid gland.

The Excretory System includes the blood-filtering organs or kidneys, their ducts the ureters, and a reservoir or bladder, into which these open. The permanent kidneys and their ducts are formed from the metanephros and metanephric ducts of the embryo. The bladder arises as a diverticulum from the hind end of the gut, being in fact a remnant of the intra-embryonic part of the allantois. It loses its connection with the gut, and the ureters which originally opened into the rectum follow the bladder and open into it.

The kidneys are dark-red ovoid bodies lying on the dorsal wall of the abdomen; the one on the left is further down than that on the right because of the position of the stomach on the left side. When a kidney is dissected, a marked difference is seen between the superficial cortical part and the deeper medullary substance. On papillæ or pyramids in the very centre, the coiled excretory tubules open, and empty the water and waste-products which they contain into the "pelvis" or mouth of the ureter.

The ureters run backward along the dorsal wall of the abdomen, and open into the bladder, a thin-walled sac lying in front of the pelvic girdle.

In front of each kidney lies a yellow adrenal body, of unknown physiological significance.

Reproductive Organs.—(*a*) *Male.* The testes arise on the dorsal abdominal wall near the kidney, but as the rabbit becomes sexually mature, they are loosened from their original attachment, and pass out on the ventral surface, as if by a kind of normal rupture, into the scrotal sacs.

Each testis is moored to the base of the muscular scrotal sac, and is bordered by a mass of convoluted tubes—the epididymis, consisting of the caput epididymis anteriorly, the larger cauda epididymis posteriorly, and a narrow band between them.

Through the tubes of the epididymis (the modified mesonephros), the spermatozoa developed in the testes are collected into the vas deferens (the modified Wolffian duct), which arises from the cauda epididymis, ascends to the abdomen, extends round to the dorsal surface of the neck of the bladder, and there opens beside its fellow into a median sac called the uterus masculinus. In many Mammals paired diverticula, known as seminal vesicles, are connected with the ends of the vasa deferentia, but they are not developed in the rabbit.

The uterus masculinus is the homologue of the vagina in the female, and seems to arise from the Müllerian ducts. It opens into the urethra which runs backwards from the bladder, and the urinogenital canal thus formed is continued through the penis.

Beside the uterus masculinus and the vasa deferentia, there are lobed prostate glands opening by several ducts

into the urinogenital canal. Behind the prostate on the dorsal wall of the urinogenital canal lie two Cowper's glands.

The penis, which projects in front of the anus behind the pubic symphysis, has vascular dorsal walls (corpus spongiosum), stiff ventral walls (corpora cavernosa), and is invested by a loose sheath of skin—the prepuce. At the side of the penis lie the two perineal glands.

(*b*) *Female.* The ovaries are small oval bodies about three quarters of an inch in length, attached behind the kidneys to the dorsal abdominal wall, exhibiting on their surface several clear projections or Graafian follicles, each of which encloses an ovum.

The ova when mature burst from the ovaries and are caught by the adjacent anterior openings of the oviducts. The oviducts are modified Müllerian ducts, and are differentiated into three regions. The anterior portion or Fallopian tube is narrow, slightly convoluted, with a funnel-shaped ragged or fimbriated mouth lying close to the ovary. The median portion or uterus is the region in which the fertilised ova become attached and are developed. In the rabbit, the uterine regions of the two oviducts are distinct, forming what is called a double uterus. In most cases, the uterine regions of the two oviducts coalesce, forming a bicornuate or a single uterus, according to the completeness of the fusion. In all mammals above Marsupials, the posterior parts of the two oviducts unite in a median tube, the vagina.

The vagina unites with the neck of the bladder and forms the wide but short urinogenital canal or vestibule which opens at the vulva ventral to the anus. On the ventral wall of the vestibule, lies the clitoris, a small rod-like body—the homologue of the penis. On the dorsal wall lie two small Cowper's glands, and there are also perineal glands as in the male.

The development of the fertilised ovum is in most respects like that of the hedgehog, which has been already described. In the guinea-pig and some other Rodents, but not in the rabbit, there is a remarkable inversion of the germinal layers.

There is in the rabbit, as in all Rodents, a provisional yolk-sac placenta. The allantoic placenta is discoidal and deciduate.

SYSTEMATIC SURVEY OF THE ORDERS OF MAMMALIA.

I. Sub-Class—PROTOTHERIA or ORNITHODELPHIA—Order Monotremata.
II. „ —METATHERIA or DIDELPHIA—Order Marsupialia.
III. „ —EUTHERIA or MONODELPHIA or PLACENTALIA.

Orders of EUTHERIA.

1. Edentata.
2. Sirenia.
3. Ungulata.
   - Artiodactyla } Ungulata Vera.
   - Perissodactyla } Ungulata Vera.
   - Hyracoidea.
   - Proboscidea.
   - Extinct sub-orders.
4. Cetacea.
   - Mystacoceti—baleen cetaceans.
   - Archæoceti—(extinct types).
   - Odontoceti—toothed cetaceans.
5. Rodentia.
   - Simplicidentata.
   - Duplicidentata.
6. Carnivora.
   - Carnivora Vera.
   - Pinnipedia.
   - Creodonta (extinct).
7. Insectivora.
   - Insectivora Vera.
   - Dermoptera.
8. Chiroptera.
   - Megachiroptera.
   - Microchiroptera.
9. Lemuroidea. } = Primates.
10. Anthropoidea. } = Primates.
    - *Hapalidae.*
    - *Cebidæ.*
    - *Cercopithecidæ*
    - *Simiidae.*
    - *Hominidæ.*

SOME CONTRASTS BETWEEN THE THREE SUB-CLASSES.

PROTOTHERIA. ORNITHODELPHIA. MONOTREMES.	METATHERIA. DIDELPHIA. MARSUPIALS.	EUTHERIA. MONODELPHIA. PLACENTALS.
Oviparous. No mammæ are developed.	Young born prematurely after very short gestation; after birth they are usually nurtured in a pouch; there is no true placenta.	During gestation the young are vitally united to the mother by a placenta.
Large ova, with much yolk, meroblastic segmentation.	Small ova, holoblastic segmentation, large yolk-sac, with villi from its surface.	Small ova virtually without yolk, holoblastic segmentation, the yolk-sac is small except in Rodentia, Insectivora, and Chiroptera, in which it forms a provisional yolk-sac placen ta
Smooth brain. Large anterior commissure. Small corpus callosum.	Smooth brain. Large anterior commissure. Small corpus callosum.	Convoluted brain. Small anterior commissure. Large corpus callosum.
A cloaca into which the rectum and the urinogenital sinus open.	Anus and urinogenital aperture surrounded by the same sphincter muscle; in the females there is a rudimentary cloaca except in kangaroos.	Anus and urinogenital aperture quite distinct.
The vasa deferentia open into the urinogenital sinus, the canal of the penis is not continuous with the vasa deferentia.	The scrotum is in front of the penis.	The scrotum (when present) is behind the penis.
The oviducts (without differentiated regions) open separately into the urinogenital sinus; the ureters open not into the bladder but into the urinogenital sinus.	Two uteri and two vaginæ; sometimes the proximal portions of the vaginæ fuse in a median cæcum or tube; the ureters open into the bladder.	The uteri are generally more or less united in one, the vaginal portions are united; the ureters open into the bladder.
The coracoids reach the sternum.	The coracoids are merely small processes of the scapulæ.	The coracoids are merely small processes of the scapulæ.
Many other skeletal peculiarities, thus:—the sutures of the skull close, the vertebral centra have no epiphyses, etc.		
Two epipubic bones	Generally two epipubic bones. The angle of the lower jaw is inflected (exc. in *Tarsipes*.)	No epipubic bones.
Body temperature 25°–28° C.	Body temperature 32°–36° C.	Body temperature 35°–40° C.

Sub-class PROTOTHERIA (Syn. ORNITHODELPHIA), Order Monotremata.

This sub-class includes the duckmole (*Ornithorhynchus anatinus*), the spiny ant-eater (*Echidna aculeata*), and a third form resembling *Echidna*, but often referred to a distinct genus as *Proechidna bruignii.* These are the lowest Mammals, and exhibit affinities with Sauropsida, and perhaps even with Amphibia. It need hardly be said that they have no special affinities with Birds. We have already contrasted them with the other Mammals, but may again state their more important characteristics.

General Characters of Prototheria.

The duckmole is found in the rivers of Australia and Tasmania; *Echidna*, in Australia, Tasmania, and New Guinea; *Proechidna* in New Guinea.

In *Ornithorhynchus*, the skin is covered with soft fur; in *Echidna* and *Proechidna*, there are spines among the hairs. The mammary glands in the female *Ornithorhynchus* open on a flat patch; in *Echidna*, in a depressed area around which a temporary pouch seems to be developed.

The vertebral centra bear no epiphyses. The skull is smooth and polished as in Birds, for the sutures of the bones do not persist. The rami of the lower jaw do not unite in front, and they have no ascending process. In *Ornithorhynchus*, there are true mammalian teeth, but only in the young; in *Echidna*, none are present. Cervical ribs remain distinct for a time at least; the odontoid process of the second vertebra or axis is long and not fused to the centrum. The coracoids reach the præsternum, there are large epi- or pre-coracoids and a T-shaped interclavicle, the whole girdle resembling that of Lizards. In *Ornithorhynchus*, the ischia form a long ventral symphysis; in *Echidna*, the acetabulum socket for the femur is incompletely ossified as in Birds; the pubes bear epipubic bones, as in Marsupials. On the side of the tarsus, in the duckmole, there is a spur perforated by the duct of a gland. This spur persists in the males, is rudimentary in the females. The male *Echidna* has a similar but smaller spur.

The brain is smooth, the cerebellum is not covered by the cerebrum, there is a large anterior commissure and but a small corpus callosum.

The food-canal ends in a cloaca.

The right auriculo-ventricular valve in *Ornithorhynchus* is partly muscular as in Birds, while in other Mammals it is membranous, and worked by papillary muscles which do not enter into the substance of the valve. The temperature of the body is said to be about 25–28° C.

The ureters open, not into the bladder, but into the urinogenital canal.

The testes remain abdominal. The left ovary is larger than the right, as in Birds. The vasa deferentia open separately in the urinogenital canal. So in the female do the oviducts, and these have no fringed abdominal apertures nor distinct uterine region. The penis is attached to the ventral wall of the cloaca, and its canal is not continuous with that of the vasa deferentia.

The ova are large, have abundant yolk, and undergo meroblastic segmentation. The Prototheria are oviparous.

The duck-mole, duck-billed platypus, or water-mole, lives beside lakes and rivers. It swims by means of its fore-limbs, which are webbed as well as clawed; it grubs for aquatic insects, crustaceans, and worms in the mud at the bottom of the water. It seems to collect small animals in its cheek-pouches, chewing them at leisure with its eight horny jaw-plates. It makes long burrows in the banks, often with two openings, one above, one under the water. The animal is shy, and dives swiftly when alarmed. When about to sleep, it rolls itself into a ball. In the recesses of the burrows the eggs are laid, two at a time. The egg measures about three-quarters of an inch in length, and is enclosed in a "strong, flexible, white shell," through which the young animal has to break its way.

The full-grown duckmole measures from eighteen to twenty inches in length; the male slightly exceeds his mate. The fur is short and soft, dark brown above, lighter beneath. The jaws are flattened like the bill of a duck, and covered with naked skin, which forms a soft, sensitive, collar around the region where the bill joins the skull. The eyes are very small; there is no external ear-flap or pinna; the nostrils lie near the end of the upper part of the bill. The tail is short and flat.

Horny plates, two on each jaw above and below, serve as teeth in the adult. The true teeth are calcified as in other mammals, but they do not last very long, being soon worn away and shed. The cheeks form capacious pouches. The digits are clawed and connected by a web which is best developed on the fore-limbs. The spur borne on the heel seems to be sometimes used as a weapon, and as it persists only in the males, is likely useful in contests between rivals.

Echidna and *Proechidna* live in rocky regions, are mainly nocturnal in habit, and burrow rapidly, legs foremost. They feed on ants, which are caught on the rapidly mobile, slender, viscid tongue. They are obviously well-protected by their spines, and are very hardy.

Strong spines occur thickly in *Echidna*, more sparsely in *Proechidna*, among the hairs. The snout is prolonged into a slender tube. The limbs bear five toes, two of which in *Proechidna* are often without claws and somewhat rudimentary. In *Echidna*, the eggs seem to be hatched in a temporarily developed pouch.

Sub-class METATHERIA OR DIDELPHIA,—Order Marsupialia.

With the exception of the N. American opossums, all the Marsupials now alive are natives of Australasia. But fossil remains found in Europe and America show that they once had a wide range. As there are no higher mammals indigenous to Australasia, it seems as if the insulation of that region had occurred after the Marsupials had gained possession of the region, but before any mammalian competitors had appeared on the scene. Thus saved and insulated, the Marsupials have developed in many different directions, the families included in this order being very diverse.

General Characters of Marsupials.—The brain is less evolved than in higher mammals, for the convolutions are simple or absent, the anterior commissure is large, the corpus callosum is still small. In the skeleton there are several peculiarities; thus the angle of the lower jaw is more or less inflected, except in the genus *Tarsipes;* there are generally two epipubic or "marsupial" bones in front of the pubic symphysis; there are more incisors above than below (except in the wombat), and the number of incisors sometimes exceeds three on each side. A common sphincter muscle surrounds the anus and the urinogenital aperture, and in the females (except kangaroos) the anus lies so much within the urinogenital sinus that the arrangement may be described as cloacal. The scrotal sac containing the testes lies in front of the penis. The genital ducts of the females are often separate throughout, so that there are two uteri and two vaginæ. But the bent proximal parts of the vaginæ

sometimes fuse and form a cæcum, which, according to the degree of fusion, may be a single tube or divided by a partition. Moreover, in Bennett's kangaroo, the cæcum opens independently into the cloaca between the apertures of the distal portions of the vaginæ.

The allantois is small, and does not unite with the subzonal membrane. The yolk-sac is large and adheres to a portion of the subzonal membrane. From this region in some cases, *e.g.*, opossums, villi are given off, which enter into close connection with the glands of the uterine wall. The unborn young seems to derive its nourishment from the yolk-sac.

The gestation is short, lasting only a fortnight in the opossum, about five weeks in the kangaroo. Except in some opossums, there is a marsupial pouch, usually with a forward-directed aperture. Within this pouch are the teats, and here too the delicate young are nurtured after birth. The milk is forced down the throat of the young, the mammary gland being compressed by the cremaster muscle which covers it.

Families of Marsupials.

A. POLYPROTODONTIA. "Incisors numerous, small, subequal. Canines larger than the incisors. Molars with sharp cusps."

Family, Didelphyidæ:—American opossums, distributed from the United States to Patagonia, arboreal in habit, usually carnivorous or insectivorous in diet. The limbs have five digits with claws, the hallux is opposable. The tail is generally long and often prehensile. The stomach is simple, the cæcum small. The pouch is generally absent, but the young are often carried on the back of the mother, their tails coiled round hers. Dentition, $\frac{5134}{4134}$.

Examples:—The Virginian or crab-eating opossum (*Didelphys marsupialis*), with a pouch; the woolly opossum (*D. lanigera*); the aquatic Yapock (*Chironectes*) which feeds on fish and smaller water animals.

Family Dasyuridæ:—Carnivorous or insectivorous Marsupials. The limbs have clawed digits, five in front, four or five behind. The canines are generally large. The stomach is simple, there is no cæcum.

Examples:—The Tasmanian wolf (*Thylacinus*), of dog-like form, dentition, $\frac{4134}{3134}$, and the Dasyure (*Dasyurus*), civet-like, dentition, $\frac{4124}{3124}$, are specialised as carnivores. The members of the

genus *Phascogale* are small and insectivorous. The banded ant-eater (*Myrmecobius*) of W. and S. Australia, a somewhat squirrel-like animal, has a long thread-like protrusible tongue and more teeth than any other Marsupial $\frac{4135 \text{ or } 6}{3135 \text{ or } 6}$.

Family Peramelidæ:—The burrowing bandicoots, all small in size, insectivorous or omnivorous in diet. In the fore-feet, two or three of the middle toes are well-developed and clawed, the others being rudimentary; in the hind-feet, the hallux is small or absent, the second and third toes are very slender and united in the same fold of skin, the fourth toe is very large, the fifth smaller,—the whole foot suggesting that of the kangaroo. The stomach is simple, the cæcum not large. Clavicles are absent. Dentition, $\frac{4 \text{ or } 5\ 134}{3\ \ 134}$.

Examples:—The true bandicoot (*Perameles*); the native rabbit (*Peragale lagotis*); the rat-like *Chœropus*.

B. DIPROTODONTIA. "Incisors usually $\frac{3}{1}$; the first large and cutting; the upper canines generally, the lower canines always small or absent; the molars with bluntly tuberculated or transversely ridged crowns."

Family Phascolomyidæ:—The Wombats, terrestrial, vegetarian nocturnal Marsupials, somewhat bear-like in appearance. The dentition is rodent-like, $\frac{1014}{1014}$, the teeth have persistent pulps, the incisors are chisel-edged, there being no enamel except in front. The fore-feet have five distinct toes with strong nails; the hind-feet have a small nailless hallux, the second, third, and fourth toes partly united by skin, the fifth distinct. The tail is very short. The stomach is simple, the cæcum very short.

There is but one genus—*Phascolomys*, with three species.

Family Phalangeridæ:—Small woolly arboreal nocturnal Marsupials, with vegetarian or mixed diet. The fore-feet have five distinct toes; the hind-feet have a large, nailless, opposable hallux, the second and third toes are narrow and bound together by skin, the fourth and fifth free. The tail is generally long and prehensile. The stomach is simple, the cæcum usually large. Average dental formula, $\frac{3,\ 1,\ 2\text{–}3,\ 3\text{–}4}{1,\ 0,\ 0\text{–}2,\ 3\text{–}4}$.

Examples:—The grey Cuscus (*Phalanger orientalis*); *Tarsipes*, a small mouse-like animal which feeds on honey, and is remarkable in having no inflection of the angle of the mandible and no cæcum; the flying phalangers (*Petaurus*), with a parachute of skin extending from the little finger to the ankle; the Koala or "native bear" (*Phascolarctos cinereus*), a relatively large form about two feet in length.

Family Macropodidæ:—Kangaroos, herbivorous terrestrial Marsupials. Dentition, $\frac{3, 0\text{–}1, 2, 4}{1,\ 0,\ 2,\ 4}$. The incisors are sharp and suited for cropping herbage. The hind-legs are usually larger than the

fore-legs, and the animals move by leaps. The fore-feet have five clawed digits; in the hind-feet, the hallux is absent except in one case, the second and third toes are rather slender, the fourth is very large and has a strong claw, the fifth is somewhat smaller, all the four toes are bound together by the skin. The tail is long. The stomach is sacculated.

Examples:—The true Kangaroos, *e.g.*, *Macropus;* the rat-kangaroos or potoroos (*Potorous*); the genus *Hypsiprymnodon*, with a foot approaching that of the Phalangers.

The true Kangaroos, belonging to the genus *Macropus*, include the largest living Marsupials, but within the genus there is much difference in size.

The grey Kangaroo (*M. giganteus*), lives on the grassy plains of Eastern Australia and Tasmania, and is as tall as a man; the Wallabies, at home in the bush, are smaller, and some are no bigger than rabbits.

The hind-limbs seem disproportionately long, and are well suited for rapid bounding. The long tail carried horizontally, helps to balance the stooping body as the animal leaps, and it gives additional stability to the erect pose. The fore-limbs sometimes come to the ground when the animal is feeding, and in the largest species, they are strong enough to throttle a man.

The fore-limbs bear five clawed digits, the hind-feet have only four. The hallux is absent; the fourth toe is very long; the fifth is about half as large; the third and second are too slender to be useful for more than scratching, and are bound together by the skin, being what is technically called syndactylous. The length of the hind-limb is due to the tibia and fibula, and to the foot. The clavicles and fore-arm are well developed. The epipubic or marsupial bones are large.

The Kangaroos feed on herbage, and are often hunted down on account of the damage which they do to pastures and crops. The sharp incisors $\frac{3}{1}$ are suited for cropping the grass and herbs, which the ridged and tuberculated molars $\frac{4}{4}$ crush. In many ways the dentition is difficult to understand, thus premolars and molars move forward as the animal grows older.

As the Kangaroos are exclusively herbivorous, it is not surprising to find that the stomach is large and complex, with numerous saccules on its walls. The whole gut is long, and there is a well-developed cæcum.

Among extinct Marsupials there were some gigantic forms, notably *Diprotodon australis* as large as a Rhinoceros. It is likely that many of the early Mesozoic mammals were Marsupials.

A remarkable new type of Marsupial (*Notoryctes typhlops*) has been recently discovered by Dr E. C. Stirling. Four or five cervical vertebræ are fused, there is a keeled sternum, and a bird-like pelvis. The eyes are rudimentary and beneath the skin. The marsupial bones are small nodules. The animal is mole-like and a rapid burrower.

Sub-class EUTHERIA—Order I. Edentata.

This order includes five very distinct families with living representatives—the sloths, the ant-eaters, the armadillos, the pangolins, and the aard-varks. The first three families are found in the New World, the last two in the Old World.

So diverse are the five types that only one characteristic can be stated :—the teeth are either absent or simple and imperfect. When present they are uniform, and except in *Tatusia* and *Orycteropus* there is only one set ; moreover, they are without roots, and grow from persistent pulps, are without enamel, and are never developed on the fore part of the mouth.

The modern Edentata are specialised survivors of a waning order, whose extinct representatives seem to have been larger and more primitive. The modern forms usually have protective peculiarities of structure and habit which secure their persistence. Thus some are arboreal, others are burrowers, and many are covered with strong armature of bone or of horn. It is interesting to observe how very varied the nature of the placenta is :—

a dome-shaped disc (deciduate) in the sloths,
dome-shaped or discoidal (deciduate) in the ant-eaters,
discoidal (deciduate) in the armadillos,
diffuse (non-deciduate) in the pangolins,
zonary (deciduate) in the aard-varks.

Families of Edentata.

1. Bradypodidæ—Sloths.—The three-toed sloths (*Bradypus*) and the two-toed sloths (*Cholœpus*) are restricted to the forests of South and Central America. They are the most arboreal of mammals, passing their whole life among the branches, to which they hang and along which they move back downwards. They are solitary, nocturnal, vegetarian animals, sluggish as their name suggests, and with a very firm grip of life. Their shaggy hides harmonise with the mosses and lichens on the branches, and the protective resemblance is increased by the presence of a green alga on the hair. Their food consists of leaves and shoots and fruits.

The body is covered with coarse shaggy hair ; the head is rounded and bears very small external ears ; the fore-limbs are longer than the hind-limbs, and the two or three digits are bound together by skin and have long claws ; the tail is rudimentary.

Concerning the skeleton we may note the single set of $\frac{5}{4}$ rootless, unenamelled teeth, the incomplete zygomatic arch with a descending process from the jugal, the presence of clavicles, the rod-like appearance of the embryonic stapes, the occurrence of nine cervical vertebræ in *Bradypus*, of six in *Cholœpus*.

As in most herbivorous animals, the stomach is complex, but there is no cæcum. In the limbs the main blood-vessels break up into numerous parallel branches. The uterus is simple, the vagina seems to be originally divided by a median partition, the placenta is a deciduate dome-shaped disc. One young one is born at a time.

2. Megatheriidæ or Ground-Sloths—extinct forms of large size, intermediate between the sloths and the ant-eaters. Their remains are found in Pleistocene deposits in N. and S. America. The genus *Megatherium* exceeded the Rhinoceros in size.

3. Myrmecophagidæ—the ant-eaters, toothless, hairy animals, literally Edentate, with long thread-like protrusible tongues viscid with the secretion of greatly enlarged submaxillary glands. One form, *Myrmecophaga jubata*, is terrestrial, the others belonging to the genera *Tamandua* and *Cycloturus* are arboreal. All feed on insects. All are Neotropical. The skull is long; the third finger is greatly developed, the others are small; the pes has four or five almost equal, clawed toes; the clavicles are rudimentary; the tail is long and sometimes prehensile. The brain is well convoluted. The uterus is simple. The placenta is dome-like or discoidal.

4. Dasypodidæ—the armadillos, all S. American except *Tatusia novemcincta*, which extends as far north as Texas. They are nocturnal, omnivorous animals, able to run and burrow rapidly. They are unique among living mammals in having a dermal armature of bony scutes united into shields and rings, and covered by horny epidermis. The teeth are numerous, simple, of persistent growth, and in most cases of one set. Clavicles are well-developed. The digits have strong claws or nails. The brain has large olfactory lobes; the cerebral hemispheres have few convolutions. The tongue is long and protrusible, and the submaxillary glands are large. The stomach is simple. The uterus is simple. The placenta is discoidal and deciduate.

   Examples:—*Dasypus*, *Chlamydophorus*, *Tatusia*.

5. Glyptodontidæ—extinct Pleistocene types, mostly S. American, but represented in Mexico and Texas. The body was often huge, and was covered by a solid carapace of great strength. "Why such a form as the Glyptodon should have failed to keep his ground is a great mystery; nature seems to have built him, as Rome was built, for eternity." (W. K. Parker.)

6. Manidæ—the Ethiopian and Oriental Pangolins, covered dorsally with overlapping horny scales. They are terrestrial, burrowing animals, but sometimes climb trees. They usually feed on termites. There are no teeth, the tongue is long and protrusible. The uterus is bicornuate, the placenta diffuse and non-deciduate. There is one extant genus *Manis*.

7. Orycteropidæ—the Ethiopian Aard-varks, represented by two species of *Orycteropus*, ranging from S. Africa to Egypt. They are shy, nocturnal animals, living in burrows, feeding on termites. There are numerous complex teeth of two sets. The skin bears scanty bristles. The mouth is tubular, and the tongue is narrow and protrusible. The digits bear nails suited for digging. The uterus is bicornuate, the placenta broadly zonary.

Order 2. Sirenia—Sea Cows.

A small moribund order of sluggish, aquatic, seaweed-eating Mammals, in no direct way connected with Cetaceans, possibly related to Ungulates, but certainly primitive. There are two living genera, *Halicore* (Dugong), and *Manatus* (Manatee), and one recently exterminated (*Rhytina.*)

The Sirenia are sluggish animals, with massive heavy bones, a plump body, some oil, and sparse hair. They are aquatic, with fish-like form, no trace of hind-limbs, flipper-like fore-limbs, no external ear, valved nostrils, networks in the arteries (useful in prolonged immersion). They are herbivorous, and like others of similar habit have a chambered stomach, a long intestine, and a cæcum.

They are primitive, and with this fact may be associated the abdominal testes, the absence of separate epiphyses on the vertebræ (as in Prototheria), the small, rather smooth brain.

The body is fish-like, the head rounded, the skin is thick and tough, with sparse bristles, mostly about the mouth.

The paddle-shaped fore-limbs have, at most, rudimentary nails; there are no hind-limbs. The skull is not like that of Cetaceans. The nasals are, at most, rudimentary. There are no canine teeth. The vertebræ have no epiphyses. There are chevron bones below the tail. There are no clavicles. The pelvis is rudimentary.

The brain is small and has few convolutions. The nostrils are valved, and lie at the end of the snout. The small eyes have imperfect eyelids, but have a nictitating membrane. There are no external ears. In the mouth there are horny crushing plates. The stomach is chambered, and there is a cæcum. The ventricles are separated by a

cleft. There are retia mirabilia on the arteries. The testes are abdominal in position. The uterus is bicornuate. Two teats lie behind the arm-pits. The placenta of the dugong is zonary, wholly or in great part non-deciduate.

MANATEE (*Manatus*).	DUGONG (*Halicore*).
Neck vertebræ reduced to six.	The usual seven neck vertebræ.
Abortive incisors ($\frac{2}{2}$) in both sexes.	Two tusk-like incisors persist in the male.
Molars ($\frac{11}{11}$, six or so at a time); uniform, with square enamelled crowns, and tuberculated, transverse, grinding ridges.	Molars ($\frac{5}{5}$ or $\frac{6}{6}$, 2 or 3 at a time), primitive, with persistent pulps and no enamel.
Premaxillæ almost straight.	Premaxillæ crooked downwards.
Tail rounded.	Deeply notched tail.
Rudimentary nails on fingers.	Nail-less digits.
Cæcum divided.	Thick and single cæcum.
M. australis and *M. senegalensis* live in the mouths of great rivers which flow into the tropical Atlantic.	*H. tabernaculi*, E. African coast and Red Sea; *H. dugong*, Indian and Pacific Oceans eastward from the home of the last species to the Philippines; *H. australis*, E. and N. Australia.

The genus *Rhytina* was toothless, with a slightly crooked snout, small head and arms, and thick naked skin. Steller's Sea-Cow (*R. stelleri*), the only known species, from the north Pacific, seems to have been exterminated in the last century.

The order was once much larger. Fossil forms occur in Tertiary strata. The most important is *Halitherium*, a less specialised Sirenian than those still extant, and with at least traces of hind-limbs.

Order 3. Ungulata.

Hoofed Animals—Artiodactyla, Perissodactyla, Hyracoidea, Proboscidea, and extinct sub-orders.

This large and somewhat heterogeneous order includes pigs, hippopotamus, camels, cattle, deer, tapirs, rhinoceros, horses, hyrax, elephants, and some other distinct types.

They are terrestrial, and for the most part herbivorous animals. Their digits generally end in hoofs or at least in broad nails. In the adults of the modern types there are no clavicles. The teeth are diverse and of two sets, the milk set in part persistent until the animal attains maturity.

Ungulata Vera :—Artiodactyla and Perissodactyla.

In these typical Ungulates, the feet are never plantigrade. In modern types there are never more than four functional toes. The os magnum of the carpus articulates freely with the scaphoid. The brain is well convoluted. The testes descend into a scrotum. The uterus is bicornuate. The placenta is non-deciduate, and either diffuse or cotyledonary.

ARTIODACTYLA—PIGS, CAMELS, CHEVROTAINS, and RUMINANTS.	PERISSODACTYLA—TAPIRS, RHINOCEROS, HORSES.
The third and fourth digits of each foot are equally developed, and the line halving the foot runs between them.	The third digit occupies the middle of the foot, is largest, and is symmetrical on itself, so that the line halving the foot bisects the third digit.
The premolars and molars are usually different.	The premolars resemble the molars.
There are nineteen dorso-lumbar vertebræ.	There are almost always twenty-three dorso-lumbar vertebræ.
The femur has no third trochanter.	The femur has a third trochanter.
The astragalus has always equal articular facets for the navicular and for the cuboid. The calcaneum has an articular facet for the fibula.	The astragalus has a large facet for the navicular, a small facet for the cuboid. The calcaneum does not articulate with the lower end of the fibula.
The stomach tends to be complex, and the cæcum is small.	The stomach is always simple, and the cæcum is large.
The mammæ are few and inguinal, or numerous and abdominal.	The mammæ are always inguinal.
The placenta is diffuse or cotyledonary.	The placenta is always diffuse.

Sub-Order Artiodactyla—Even-toed Ungulates.

Pigs and Hippopotamus (Suina), Camels (Tylopoda), Chevrotains (Tragulina), and Ruminants (Pecora) like Cattle and Deer.

The general characters of this sub-order have been stated above in contrast to those of Perissodactyla. The equal development of the third and fourth digits, the fact that the premolars have a single lobe while the molars have two, the nature of the ankle bones, the tendency that the stomach has to be complex (as in Camels and Ruminants) are important characteristics. There are others of less obvious importance, such as the absence of the alisphenoid canal which in Perissodactyla encloses the external carotid artery as it passes along the alisphenoid.

There are primitive extinct Artiodactyla which connect the four modern groups—Suina, Tylopòda, Tragulina, and Pecora. Thus they unite the bunodont types, such as pigs, with cone-like tubercles on the crowns of the molars, and the selenodont types, such as cattle, with the tubercles expanded from before backwards and curved in crescents.

Group 1. Suina—Hippopotamus, Pigs, and Peccaries. The molars are bunodont; the third and fourth metacarpals and metatarsals are not completely fused as "cannon-bones."

Hippopotamidæ:—huge African mammals, included in the single genus *Hippopotamus*. They spend the day in the rivers and lakes, swimming and diving well, but usually remaining concealed. At night they come on land and browse on grass and herbage. The skin is extremely thick, with a few hairs restricted to the snout, head, neck, and tail. There are four toes on each foot, all reaching the ground. The rootless incisors continue growing; so do the large curved canines; the dental formula is $\frac{2\text{–}3,\ 143}{1\text{–}3,\ 143}$. The stomach has three chambers; there is no cæcum.

Suidæ:—the Old World boars and pigs, characterised by the mobile snout and terminal nostrils. There are four well-developed digits on the narrow feet, but the second and fifth do not reach the ground in walking. The incisors are rooted, the upper canine curves outwards or upwards. The stomach is almost simple, but has more or less of a cardiac pouch; there is a cæcum.

Examples:—*Sus*, $\frac{3}{3}\frac{1}{1}\frac{4}{4}\frac{3}{3}$; *Babirusa* $\frac{2}{3}\frac{1}{1}\frac{2}{2}\frac{3}{3}$, the male with remarkable canines, the upper pair growing upwards from their base through the skin, arching backwards as far as the forehead, and sometimes forwards and downwards again, the lower pair with a more or less parallel course; *Phacochærus*, the wart-hog.

Dicotylidæ:—the New World Peccaries (*Dicotyles*), with a snout like that of pigs; with four toes on the fore-feet, and three behind. The incisors are rooted, the upper canines are directed downwards, the dental formula is $\frac{2}{3}\frac{1}{1}\frac{3}{3}\frac{3}{3}$. The stomach is complex, and there is a cæcum.

Group 2.—Tylopoda, comprising the family Camelidæ—the Camels of the Old World and the Llamas of S. America. The limbs are long, with only the third and fourth digits developed; the two metacarpals and metatarsals are united for the greater part of their length, but there is a deep distal cleft; the tips of the digits have very incomplete hoofs, and the animals walk on a broad pad of skin surrounding the middle phalanges. The femur is long and vertical, and the knee is low down. Of the three upper incisors only one persists in adult life, as an isolated sharp tooth, those of the lower jaw are long and slope forwards. There are canines both above and below. The molars are selenodont. The camels and llamas ruminate, and the stomach is divided into three chambers, of which the first two have remarkable pouches

on their walls which can be filled with fluid and closed by sphincter muscles. The Camelidæ are unique among Mammals in having oval, instead of circular red blood-corpuscles. The placenta is diffuse.

Examples:—*Camelus*, $\frac{1\,1\,3\,3}{3\,1\,2\,3}$, the Arabian camel (*C. dromedarius*) has a dorsal hump of fat, the Bactrian camel (*C. bactrianus*) has two humps. The genus *Auchenia*, $\frac{1\,1\,3\,3}{3\,1\,2\,3}$, includes the llama, alpaca, huanaco, and vicugna of S. America, smaller forms than the camels, and without humps.

Group 3.—Tragulina, comprising the family Tragulidæ or Chevrotains. These are small animals, "intermediate in their structure between the Deer, the Camels, and the Pigs." There are four complete toes on each foot, but the second and fifth are slender; the third and fourth metacarpals and metatarsals are fused in *Tragulus*, free in the other genus *Dorcatherium;* the fibula is complete. There are no upper incisors, the upper canines are long and pointed especially in the males, the lower canines are like incisors, the dental formula is $\frac{0\,1\,3\,3}{3\,1\,3\,3}$. The Chevrotains ruminate, and the stomach is divided into three chambers. The placenta is diffuse. The chevrotains are often confusedly associated with the musk-deer (*Moschus*) with which they have no special affinities.

Species of *Tragulus* (smallest among living Ungulates) occur in Indo-Malaya, India, and Ceylon; one species of *Dorcatherium*, of aquatic pig-like habits, is found on the west coast of Africa.

Group 4.—Pecora or Cotylophora—the true Ruminants, including deer, giraffes, cattle and sheep. Only the third and fourth digits are complete, the fused second and third metacarpals and metatarsals form "cannon-bones." Paired outgrowths of the frontal bones are common, capped with horny sheaths in the Bovidæ, deciduous and restricted to the males in almost all Cervidæ. There are no upper incisors, and rarely upper canines; there are three pairs of lower incisors which bite against the hardened gum above, and the lower canine resembles and is in the same series as the incisors; the typical dentition is $\frac{0\,0\,3\,3}{3\,1\,3\,3}$. The stomach has four distinct compartments, a psalterium or many-plies in addition to the three which are present in Camels and Chevrotains. The placenta is cotyledonary, the villi occuring on a number of distinct patches.

The process of rumination or chewing the cud cannot be understood without considering the complex stomach. It is divided into four chambers, the paunch or rumen, the honeycomb bag or reticulum, the many-plies or psalterium, the reed or abomasum. The swallowed food passes into the capacious paunch, the walls of which are beset with close-set villi resembling velvet pile. After the food has been softened in the paunch, it is regurgitated into the mouth where it is chewed over again and mixed with more saliva. Swallowed a second time the food passes not into the paunch, but along a muscular groove on the upper wall of the globular honeycomb bag into the third chamber or many-plies. The honeycomb bag owes its name to the hexagonal pattern formed by the mucous membrane on its walls. The many-plies or

psalterium is a filter, its lining membrane being raised into numerous leaf-like folds covered with papillæ. Along these the food passes to the reed, which is the truly digestive stomach, for its smooth walls secrete the gastric juice.

Cervidæ—the widely distributed deer, absent only from the Ethiopian and Australian regions. The second and fifth digits are usually represented, often along with the distal parts of the corresponding metacarpals and metatarsals. The upper canines are usually present in both sexes. The horns, if present, are antlers, confined to the males and deciduous, except in the reindeer where they are possessed by both sexes and are permanent. They are outgrowths of the frontal bones, are covered during growth by vascular skin—the velvet, and attain each year to a certain limit of growth. After the breeding season the blood supply ceases, the velvet dies off, and an annular absorption occurs near the base. Then the antlers are shed, leaving a stump from which a fresh but larger growth takes place in the next year. The earliest (Lower Miocene) deer had no antlers, thus resembling young stags of the first year; the Middle Miocene deer had simple antlers with not more than two branches, thus resembling two-year-old stags; the parallel between the history of the race and the individual development is, as regards antlers, very exact.

Examples:—*Cervus*, most Old World deer; *Rangifer*, the reindeer; *Alces*, the elk or moose; *Capreolus*, the roe-deer; *Hydropotes*, the water-deer, without antlers; *Moschus*, the musk-deer, without antlers, with long sharp upper canines in the males, with large musk-glands.

Giraffidæ, represented solely by the giraffe (*Giraffa camelopardalis*), a tall Ethiopian animal, notable for its enormously elongated cervical vertebræ, and for its long limbs. It is gregarious in its habits, and feeds on the leaves of trees. The lateral digits are entirely absent. The dental formula is $\frac{0\,0\,3\,3}{3\,1\,3\,3}$. On both sexes there are on the forehead short erect prominences, over the union of parietals and frontals, which arise from the distinct centres of ossification, but afterwards fuse with the skull. In front of these there is median protuberance.

Antilocapridæ, represented solely by the prongbuck (*Antilocapra americana*), a North American animal with most of the characteristics of Bovidæ, but with deciduous and branched horns.

Bovidæ, the hollow-horned Ruminants widely distributed throughout the world, but without indigenous representatives in Australia, South or Central America. The second and fifth digits may be completely absent, but are often represented by minute hoofs and supporting nodules of bone. The frontal appendages, if present, consist of a solid bony core growing from the frontal and a much longer sheath of horn which grows at the base as it is worn away at the tip. They are not deciduous and are usually present in both sexes, though larger in the males.

Examples:—*Antilope*, *Gazella*, *Capra*, *Ovis*, *Bos*.

Sub-Order PERISSODACTYLA.

Horses, Tapirs, Rhinoceros, and their extinct Allies.

The middle or third digit of fore- and hind-feet is larger than the others, and symmetrical on itself. It may be the only complete digit, as in the horse, or it may be accompanied by a second and a fourth, and in the fore-foot of Tapirs and some extinct forms, by a fifth digit. No modern forms have any trace of a first digit. The astragalus has a pulley-like surface above for articulation with the tibia; its distal surface is flattened and unites to a much greater extent with the navicular than with the cuboid. The last-named bone is of less importance than in the Artiodactyla. The calcaneum does not articulate with the lower or distal extremity of the fibula. The femur has a a third trochanter or process for the insertion of muscles. There are usually twenty-three dorso-lumbar vertebræ.

As to the dentition, the premolars and molars form a continuous series, with broad transversely ridged crowns, the last premolars often very like the molars.

The stomach is simple, the cæcum is large, there is no gall-bladder.

The mammæ are inguinal; the placenta is diffuse and non-deciduate.

Families of Perissodactyla.

Family Tapiridæ. In the Tapirs (*Tapirus*), there are four digits in the manus, but the third finger is still practically median, as the fifth digit scarcely reaches the ground. The hind-foot has three digits. The dentition of the genus is $\frac{3\,1\,4\,3}{3\,1\,3\,3}$. The orbit and temporal fossa are continuous. The nose and upper lip form a short proboscis. The thick skin has but scanty hair. In habit, the Tapirs are shy and nocturnal, fond of forests and water, feeding on tender shoots and leaves. The distribution is somewhat remarkable, for some species live in Central and South America, while the rest are Malayan. The genus was once widespread, it has survived in these two widely separated regions.

Family Equidæ. In the modern horses (*Equus*), there is on each foot one functional digit—the third, with splints representing the

metacarpals and metatarsals of the second and fourth. The ulna and fibula are incomplete. The dentition is $\frac{3\,1\,4\,3}{3\,1\,4\,3}$, but the first premolar is rudimentary. The orbit is completely surrounded by bone.

The modern horses are connected by a very complete series of forms with ancestral Eocene types. The progress shows an increase of size, a diminution in the number of digits, an increased folding of the back teeth, and other differentiations. The Eocene *Phenacodus* is regarded by some as near the origin of the stock, it had five complete digits on each foot; *Hyracotherium* and *Systemodon* had only four functional digits in the manus; *Anchitherium* from the Miocene, an animal about the size of a sheep, had three digits, or three and a rudiment; *Hipparion* and *Protohippus* from the Pliocene, were as large as donkeys, and show a marked diminution of the second and fourth digits; finally, in the Pleistocene, the modern forms appeared.

The living species are the horses (*Equus caballus*), apparently originating in Asia, domesticated in prehistoric times, artificially selected into many breeds, sometimes reverting to wildness as in those imported into America and Australia by European settlers; the wild horse of Central Asia (*E. prezevalskii*); the donkey (*E. asinus*) of African origin, the wild asses of Africa and Asia, the striped African species—the quagga and the zebras.

Family Rhinocerotidæ. There is now but one genus *Rhinoceros*, species of which occur in Africa and in some parts of India and Indo-Malaya. They are large heavy Ungulates, shy and nocturnal, fond of wallowing in water or mud, feeding on herbage, shoots, and leaves. The skin is very thick, with scanty hair. One or two median horns grow like huge warts from the snout and forehead. The dentition is very variable, but the back teeth $\frac{4,\,3}{4,\,3}$ are almost uniform, there are no upper canines, but sometimes a large lower pair, there are a few incisors, but these are often small and deciduous.

There are several entirely extinct families of Perissodactyla, such as

Lophiodontidæ (Eocene), *e.g.*, *Lophiodon*, *Hyracotherium*, *Systemodon*,—a family perhaps ancestral to most of the modern Perissodactyla.

Palæotheriidæ (Eocene to Miocene), *e.g.*, *Palæotherium* and *Anchitherium*.

Other remarkable types—

Lambdotherium, *Chalicotherium*, *Titanotherium*, of elephantine size, and the specialised *Macrauchenia*—are referred to distinct families.

Sub-Order Hyracoidea.

Small Rodent-like Ungulates, represented by two genera, —*Hyrax*, living in rocky regions in E. Africa and Syria,

Dendrohyrax living on trees in W. and S. Africa. The species of both genera are able to climb on the smooth surfaces of rocks or trees.

The upper incisors have persistent pulps and are curved as in Rodents, but they are sharply pointed, not chisel-edged. The outer lower incisors (?) are straight and have trilobed crowns. There are, according to most authorities, no canines, and there is a wide space between incisors and premolars. The back teeth are very uniform and like those of Perissodactyla. The formula is $\frac{1043}{2043}$.

In the fore-feet, the thumb is rudimentary, the little finger is smaller than the median three, which are almost equal. In the hind-feet, which are like miniatures of those of the rhinoceros, the hallux is absent, and the fifth toe is rudimentary. There are no clavicles. The tail is very short.

The brain is like that of Ungulates. The stomach is divided into two parts by a constriction. In addition to the short but broad cæcum, there are two supplemental cæca lower down on the intestines. The testes are abdominal. Of the mammæ, four are on the groin and two are axillary. The placenta is zonary as in the Proboscidea and Carnivora. No extinct forms are known.

Sub-Order Proboscidea.

This sub-order is now represented by two species of elephant (*Elephas*). They occupy a somewhat isolated position, though distinctly Ungulates. As regards skull, proboscis, and teeth they are highly specialised, but their limbs are of a generalised type.

The elephants are confined to the Ethiopian and Oriental regions. They feed on leaves, young branches, and herbage. By means of the mobile proboscis they gather their food, and they drink by filling the proboscis and then ejecting the water into the mouth.

The proboscis is a muscular extension of the nose, and bears the nostrils at its tip.

The skin is strong and the hair somewhat scanty.

In the limbs, radius and ulna, tibia and fibula, are quite distinct; the radius and ulna are fixed in a crossed position;

owing to the length of the humerus and yet more of the femur elbow and knee are lower than usual; the carpal and tarsal bones have flat surfaces; the feet are broad and bear five hoofed toes embedded in a common integument. There are no clavicles.

The skull is very large, being adapted to support the proboscis and tusks, and to afford a broad insertion for the large muscles. In most of the bones there is during growth an extraordinary development of air-spaces, which communicate with the nasal passages. The nasal bones are very short; the zygomatic arch (formed anteriorly by the maxilla, medianly by the small jugal) is slender and straight. The neck is very short.

The dentition is unique. The two upper incisors or tusks are mainly composed of solid ivory; the enamel is restricted to the apex and soon wears off. As the tusks grow, their roots sink through the premaxillæ into the maxillæ. There are no canines nor premolars. The molars are very large, and the enamel is very much plaited, forming a series of transverse ridges enclosing the dentine, and united to one another by cement. Thus on the worn tooth there are numerous successive layers of enamel, dentine and cement. Extinct forms show transitions between this complex type and that of a horse. In a lifetime there may be six molar teeth on each side of each jaw; the anterior three seem to be persistent "milk-molars," the last three are true molars, but of these only one or portions of two can find space at a time. The series gradually moves forward as the front parts are worn away and cast out.

The brain is highly developed.

The stomach is simple, and there is a large cæcum.

There are two superior venæ cavæ entering the right auricle.

The testes remain abdominal in position.

There are two pectoral mammæ; the uterus is bicornuate; the placenta is non-deciduate and zonary.

Elephas, $\frac{1\,0\,6}{0\,0\,6}$, now represented by the Indian Elephant (*E. indicus*) (with parallel folds of enamel on the molars and ears of moderate size) and the African Elephant (*E. africanus*) (with lozenge-shaped folds of enamel and very large ears).

The mammoth (*E. primigenius*) belonged to the Pleistocene period, and had a wide geographical range, occurring for instance in Britain.

The genus *Mastodon* is represented by fossil remains in Miocene, Pliocene, and even in Pleistocene strata, in Europe, India, and America. The molar teeth show transitions between those of elephants and those of other Ungulates.

In *Dinotherium*, found in Miocene and Pliocene strata in Europe and Asia, the lower jaw bore an enormous pair of tusks projecting vertically downwards, and all the back teeth seem to have been in use at the same time.

Several extinct Sub-Orders.

Although we cannot describe the following remarkable types, it is important to notice their existence, for they serve to impress us with the original connectedness of what are now separate orders.

The huge Amblypoda, found in Eocene formations in W. America, had three pairs of remarkable protuberances on the top of the skull, no upper incisors, large upper canines, especially in the males, and six back teeth ($\frac{0}{3}\frac{1}{1}\frac{3}{3}\frac{3}{3}$). Example—*Uintatherium;* the genus *Coryphodon* may also be related.

Cope includes a number of generalised Eocene Ungulates under the title Condylarthra. Some seem ancestral to the Perissodactyla and Artiodactyla ; some suggest a union of ancestral Ungulates and ancestral Carnivores. The genus *Periptychus* may be regarded as an ancestral Bunodont, and *Phenacodus* as near the origin of the horse stock. But *Phenacodus* is so generalised that Cope has suggested affinities between it and not only Ungulates, but also Carnivores and Lemurs.

The tertiary strata of S. America have yielded a number of strange types, *e.g.*, *Toxodon*, *Nesodon*, and *Typotherium*, ranked in the sub-order Toxodontia and perhaps uniting Ungulates and Rodents.

From the Eocene of N. America, Marsh has disentombed a group of animals which he calls Tillodontia, *e.g.*, *Tillotherium*, which seem to combine the characters of the Ungulata, Rodentia, and Carnivora.

Order 4. Cetacea.

The Cetaceans, including whales and dolphins and their numerous relatives, are aquatic mammals of fish-like form.

The spindle-shaped body has no distinct neck between the relatively large head and the trunk, and tapers to a notched tail, the horizontal expansions of which form the flukes. The fore-limbs are paddle-like, and there are no external hints of hind-limbs. Most forms have a median dorsal fin. Hairs are generally absent, though a few bristles may

persist near the mouth. The thick layer of fat or blubber beneath the skin serves to retain the warmth of the body, and thus compensates for the absence of hair.

The general shape, the absence of external ears, the absence of an eye-cleansing nictitating membrane, the dorsal position and valvular aperture of the single or double nostril, the sponginess of the bones, the networks or retia mirabilia of blood-vessels in different parts of the body, may be associated with the aquatic life of these mammals.

The cervical vertebræ are thin and more or less fused. There is no union of vertebræ to form a sacrum, for the hind-limbs are at most very rudimentary. Under the caudal vertebræ there are wedge-shaped chevron bones.

The brain-case is almost spherical; the supra-occipital meets the frontals and shuts out the parietals from the roof of the skull; the frontals arch over the orbit; the snout or rostrum of the skull is composed of premaxillæ, maxillæ, and vomer, and of the mesethmoid cartilage.

There is only one set of teeth, of uniform pattern, and in the baleen whales they are shed before birth, being in some measure replaced in adult life by horny baleen plates developed on the palate. No clavicles are developed. Excepting the humerus, the bones of the fore-limb are stiffly jointed and flattened. There are four or five digits, of which the second and third have more than the usual number of phalanges.

The pelvis consists of two rudimentary ischia lying freely, and to these small rudiments of a limb are sometimes attached.

The rounded brain is relatively large, with well-convoluted cerebral hemispheres.

As to the alimentary system, salivary glands are rudimentary or absent, the stomach is chambered, the intestine has rarely a cæcum, the liver is but slightly lobed, there is no gall-bladder.

The heart is often cleft between the ventricles. Both arteries and veins tend to form plexuses or retia mirabilia.

The larynx is elongated so that it meets the posterior nares, and forms a continuous canal down which air passes from nostrils to lungs. Cetaceans must, of course, rise to the surface to inspire, and the expiration occurs at longer

intervals than in terrestrial mammals. The water vapour expelled along with the air from the lungs, condenses into a cloud, which is sometimes increased by an accidental puff of spray.

The kidneys are lobulated. The testes are abdominal. There are no seminal vesicles. The uterus is two-horned. The placenta is non-deciduate and diffuse. The two mammæ lie in depressions beside the genital aperture, and the milk is squeezed from special reservoirs into the mouth of the young. Usually a single young one is born at a time, and there are never more than two.

All are carnivorous, but while many feed on small pelagic animals, others swallow cuttles and fish, and *Orca* attacks other Cetaceans and seals. Most are gregarious and live in schools or herds.

The living Cetaceans are ranked in two sub-orders—the Mystacoceti or Balænoidea without teeth but with whalebone or baleen plates on the palate, and the Odontoceti or Delphinoidea, with teeth and without baleen.

Some Eocene fossils referred to the genus *Zeuglodon*, are regarded by some as representative of an extinct sub-order —Archæoceti—but D'Arcy Thompson has advanced strong arguments in favour of their affinities with Pinniped Carnivores.

In regard to the possible affinities of the Cetacea, Flower maintains (1) that the hypothesis of their descent from Ichthyopterygian reptiles is untenable, (2) that they are separated from an alliance with Carnivora by many essential characters, (3) that they exhibit several, though by no means close, affinities with Ungulata.

The same authority refers to several facts which suggest that, in their transition from terrestrial to marine life, the Cetaceans may have passed through a stage in which they lived in fresh water.

The Two Sub-Orders of living Cetaceans may be contrasted as follows (after Flower):—

MYSTACOCETI or BALÆNOIDEA, baleen Cetaceans.	ODONTOCETI or DELPHINOIDEA, toothed Cetaceans.
The teeth are absorbed before birth.	The teeth persist after birth, and are generally numerous and functional.
Whale-bone or baleen-plates develop as processes from the palate.	There is no baleen.
The skull is symmetrical.	The skull on its upper surface is more or less asymmetrical.
The nasals roof the anterior nasal passages, which are directed upwards and forwards.	The nasals, often small, do not roof the anterior nasal passages, which are directed upwards and backwards.
The maxilla does not overlap the orbital process of the frontal.	The maxilla covers most of the orbital process of the frontal.
The lachrymal is small and distinct from the jugal.	The lachrymal is fused to the jugal, or is large and helps to roof the orbit.
The tympanic is ankylosed to the periotic.	The tympanic is not ankylosed to the periotic.
The rami of the mandible are arched outwards and have no true symphysis.	The rami of the mandible are straight and form a symphisis.
All the ribs articulate only with the transverse processes of the vertebræ.	Several anterior ribs articulate by capitula with the centra of vertebræ.
The sternum is a single piece, and articulates with a single pair of ribs.	The sternum has usually several segments with which several sternal ribs articulate.
The external nostrils are separate.	The nostrils unite in a single blow-hole on the top of the head.
The olfactory organ is distinctly developed.	The olfactory organ is rudimentary or absent.
There is a short cæcum.	There is no cæcum, except in *Platanista*.
Examples:— The right-whale (*Balæna*), the hump-back (*Megaptera*), the rorqual (*Balænoptera*).	Examples:— The Sperm-whale (*Physeter*), the dolphin (*Delphinus*), the porpoise (*Phocæna*), the 'Grampus' (*Orca*), the Ca'ing Whale (*Globicephalus*), *Grampus*, the Narwhal (*Monodon*) with a horn-like tusk in the male only, the Beluga (*Delphinapterus*), the blind *Platanista* of the Ganges.

Order 5. Rodentia.

Rodents are represented in all parts of the world, and by more species than any other order of mammals. Most of them are small and most are terrestrial, but there are some arboreal and aquatic forms. All are herbivorous and gnaw their food in a characteristic way.

The dentition is characteristic. The incisors have chisel-like edges, for as the enamel is usually entirely restricted to the front of the teeth, the posterior part wears away more rapidly. The incisors are always rootless, growing from persistent pulps as they are worn away, and the same is sometimes true also of the back teeth. On the lower jaw there is never more than a pair of incisors, and in most cases the upper jaw also has only a pair. There are no canines, and the skin projects as a hairy pad into the mouth through the large gap between incisors and premolars. The premolars are always below the typical number.

The feet are plantigrade or semi-plantigrade, generally with five clawed or slightly hoofed digits. Clavicles, though often rudimentary, are generally present. The scapula has usually a long acromion process.

The condyle of the mandible is elongated from before backwards, and in gnawing the jaw moves backward and forward (unimpeded by any postglenoid process of the squamosal). The mandible has an abruptly narrowed and rounded symphysis, and a very large angular portion. The orbits are confluent with the temporal fossæ. The zygomatic arch is complete. There is generally a distinct interparietal bone. The tympanic bullæ are always developed, and are often large.

The cerebral hemispheres are smooth and leave the cerebellum uncovered.

The skin is generally thin, and the panniculus carnosus but slightly developed.

The intestine has a large cæcum, except in Myoxidæ. Special anal or perineal or other glands secreting odoriferous substances are usually developed.

The testes are inguinal or abdominal in position; only in the hares and rabbits do they completely descend into scrotal sacs.

The mammæ are on the abdomen, or on the abdomen and thorax.

The uterus is double or very markedly bicornuate. There is a provisional yolk-sac placenta; the allantoic placenta is discoidal and deciduate.

Sub-order SIMPLICIDENTATA.—Rodents with only one pair of upper incisors, with the enamel restricted to the front.

Squirrel-like (Sciuromorpha), including the following and some other families:—

Anomaluridæ, the Ethiopian arboreal genus *Anomalurus* with a lateral parachute of skin.

Sciuridæ, the squirrels (*Sciurus*), the flying squirrels—*Pteromys* and *Sciuropterus*—with a parachute of skin connecting the fore- and hind-limbs, the marmots (*Arctomys*), the prairie-dogs (*Cynomys*), the pouched marmots or sousliks (*Spermophilus*).

Castoridæ—the beaver (*Castor*).

Mouse-like (Myomorpha), including the following and some other families:—

Myoxidæ—the dormice (*Myoxus, etc.*)

Muridæ — *e.g.*, the brown rat (*Mus decumanus*), the black rat (*M. rattus*), the house-mouse (*M. musculus*), the wood-mouse (*M. sylvaticus*), the harvest-mouse (*M. minutus*), the water-voles (*Arvicola*), the American musk-rat (*Fiber zibethicus*), the lemming (*Myodes*), the hamsters (*Cricetus*).

Geomyidæ—*e.g.*, the American pouched rat (*Geomys bursarius*).

Dipodidæ—*e.g.*, the Jerboas (*Dipus, etc.*)

Porcupine-like (Hystricomorpha), including the following and some other families:—

Octodontidæ—*e.g.*, the aquatic Coypu (*Myopotamus coypu*).

Hystricidæ—*e.g.*, the porcupine (*Hystrix, etc.*)

Chinchillidæ—*e.g.*, the squirrel-like *Chinchilla*.

Dasyproctidæ—*e.g.*, the Agoutis (*Dasyprocta*), and the paca (*Cœlogenys*).

Caviidæ—*e.g.*, the guinea-pig (*Cavia*), and the S. American Capybara (*Hydrochœrus*), the largest living Rodent—measuring about four feet in length.

Sub-order DUPLICIDENTATA:—Rodents with two pairs of incisors in the upper jaw, the second pair small and behind the first pair; the enamel extends to the posterior surfaces, but is thinner there. At birth, there are three pairs of upper incisors, but the outermost are soon shed.

Lagomyidæ:—The Picas or tail-less hares (*Lagomys*), guinea-pig-like animals found on the mountains of N. Asia, in S. E. Europe, and on the Rocky Mountains.

Leporidæ:—*e.g.*, the common hare (*Lepus timidus*), the mountain hare (*L. variabilis*), the rabbit (*L. cuniculus*).

Order 6. Carnivora.

This order includes (*a*) the true Carnivores, such as lions and tigers, foxes and dogs, bears and otters; (*b*) the aquatic Pinnipedia, such as seals and walruses; and (*c*) the extinct Creodonta with several generalised types.

Most of the Carnivora feed on animal food, and the most typical forms prey upon other animals and devour their warm flesh. Most are bold and fierce animals, with keen senses and quick intelligence.

Almost all have well-developed claws; there are never fewer than four toes. The teeth are diverse, of two sets, and always rooted except in the case of the tusks of the walrus; the canines are strong and sharp; some of the back teeth are generally sharp and adapted for cutting.

"The condyle of the lower jaw is a transversely placed half-cylinder, working in a deep glenoid fossa of corresponding form." The zygomatic arch within which lie the powerful jaw-muscles is generally prominent. There are generally strong occipital and sagittal crests for the insertion of muscles. The tympanic bullæ are in most cases large.

The clavicles are incomplete or absent; the radius and ulna are always distinct; the fibula is slender but distinct.

The brain has well-marked convolutions, and the cerebellum is more or less covered over by the cerebrum.

The stomach is always simple; the cæcum is absent, or short, or simple; the colon is not sacculated.

There are no vesiculæ seminales. The uterus is bicornuate. The mammæ are abdominal. The placenta is deciduate and zonary.

Representatives of Carnivora are found in all parts of the world.

Sub-Order Carnivora Vera or Fissipedia.

The true Carnivores are for the most part terrestrial. The incisors are almost always $\frac{3}{3}$, the canines are usually large, one of the back teeth is modified as a trenchant carnassial or sectorial. The digits generally have sharp claws, which may be retractile. Within the sub-order there are three sections—Æluroidea, Cynoidea, and Arctoidea—represented respectively by cat, dog, and bear, but these types are connected by extinct forms.

ÆLUROIDEA. *e.g.*, cat, civet, hyæna.	CYNOIDEA. *e.g.*, dog, fox, wolf, jackal.	ARCTOIDEA. *e.g.*, bear, otter.
Digitigrade.	Digitigrade.	Plantigrade or sub-plantigrade.
Typical dentition, $\frac{3\,1\,3\,1}{3\,1\,2\,1}$.	Typical dentition, $\frac{3\,1\,4\,2}{3\,1\,4\,3}$.	Typical dentition, $\frac{3\,1\,4\,2}{3\,1\,4\,3}$.
The tympanic bulla is much dilated, rounded and thin-walled, and is divided into two chambers by an internal septum (except in Hyænidæ).	The tympanic bulla is dilated, but the internal septum is rudimentary.	The tympanic bulla is often depressed, and there is no hint of an internal septum.
The paroccipital process of the ex-occipital is applied to the hinder part of the tympanic bulla.	The paroccipital process is in contact with the bulla, but it is prominent.	The paroccipital process is quite apart from the bulla.
The cæcum is small, rarely absent.	The cæcum is sometimes short and simple, sometimes long and peculiarly folded.	The cæcum is absent.

In retractile claws, the last phalanx of the digit with its attached claw is drawn back into a sheath on the outer side of the middle phalanx in the fore-foot, on the upper side in the hind-foot. When the animal is at rest or is walking, the claw is retained in this bent position by an elastic ligament, and is in this way protected. When the animal straightens the phalanges, the claws are protruded.

Digitigrade animals walk on their toes only, plantigrade forms plant the whole sole of the foot on the ground, but between these conditions there are all possible gradations. Most Carnivores are sub-plantigrade, often when at rest applying the whole of the sole to the ground, but keeping the heel raised to a greater or less extent when walking.

Æluroidea—Cat-like Carnivores.

Family Felidæ, including the most specialised forms. The canines are large, the molars are reduced to $\frac{1}{1}$, the carnassials are the last premolars above (with a three-lobed blade), and the molars beneath (with a two-lobed blade). The skull is generally rounded, the zygomatic arches are wide and strong, the tympanic bullæ are large and smooth. The limbs are digitigrade, the claws retractile. There is no alisphenoid canal. The dentition of the typical genus *Felis* is $\frac{3\,1\,3\,1}{3\,1\,2\,1}$.

Examples :—The lion (*Felis leo*) in Africa, Mesopotamia, Persia, N. W. India ; the tiger (*F. tigris*), widely distributed in Asia; the leopard (*F. pardus*) in Africa, India, Ceylon, Sumatra, Borneo, etc.; the wild cat (*F. catus*); the Caffre cat (*F. caffra*) of Africa and S. Asia, venerated and mummified by the Egyptians, perhaps ancestral to the domestic cat; the puma or

couguar (*F. concolor*) from Canada to Patagonia; the jaguar (*F. onca*) also American.

Family Viverridæ:—Old World forms, such as civets (*Viverra*) of Africa and India, genets (*Genetta*) of S. Europe, Africa, and S.-W. Asia, ichneumons or mungooses (*Herpestes*) from Spain, Africa, India, Indo-Malaya.

Family Proteleidæ:—represented by *Proteles cristatus*, the hyæna-like Aard-wolf of Cape Colony.

Family Hyænidæ:—represented by the genus *Hyæna* found in Africa and S. Asia. The tympanic bulla is not divided by a septum.

Cynoidea—Dog-like Carnivores.

Family Canidæ, including forms intermediate between the cats and the bears. The dentition is more generalised than in the Felidæ, its usual formula is $\frac{3\,1\,4\,2}{3\,1\,4\,3}$. Within the tympanic bulla there is only a rudimentary septum. The paroccipital process in contact with the bulla is prominent. The cæcum is either short and simple, or long and peculiarly folded upon itself.

Examples:—The genus *Canis* has representatives in all parts of the world, the wolves (*C. lupus*, etc.), the jackals (*C. aureus*, *mesomelas*, etc.), the domestic dogs (*C. familiaris*), the foxes (*C. vulpes*, etc.), the Cape hunting dog (*Lycaon*), the bush-dog (*Icticyon*) of Guiana and Brazil, and the primitive *Otocyon megalotis* from S. Africa, with the maximum number of back teeth $\frac{3,\ 1,\ 4,\ 3\text{–}4}{3,\ 1,\ 4,\ 4}$. In the dog the dental formula is $\frac{3\,1\,4\,2}{3\,1\,4\,3}$; the upper carnassial or fourth premolar has a stout bilobed blade, the lower carnassial or first molar has a compressed bilobed blade. The skull is more elongated than in the cats; the orbits are very widely open posteriorly; the clavicles are very small; the limbs are digitigrade; there are five toes on the fore-feet, but the short thumb does not reach the ground; there are only four toes on the hind-feet, but in domestic dogs the rudiment of the hallux is sometimes enlarged as the "dew-claw;" the claws are non-retractile and blunt.

Arctoidea—Bear-like Carnivores.

The tympanic bulla shows no trace of an internal septum; the paroccipital process of the ex-occipital is quite apart from the bulla and widely separated from the mastoid process of the periotic. The limbs are plantigrade or sub-plantigrade and always bear five toes. There is no cæcum.

Family Ursidæ—Bears. The molars have broad tuberculated crowns. The three anterior premolars are usually rudimentary. The auditory bulla is depressed. *Ursus*, $\frac{3\,1\,4\,2}{3\,1\,4\,3}$, absent from Ethiopian and Australian regions, represented in the Neotropical region by only one species, elsewhere widespread.

Family Procyonidæ—The Himalayan Panda (*Ælurus fulgens*), the American raccoon (*Procyon*).

Family Mustelidæ—The otter (*Lutra*), the sea-otter (*Latax lutris*), the skunk (*Mephitis*), the badger (*Meles*), the ratel (*Mellivora*), the marten, sable, polecat, stoat, ermine, weasel (*Mustela*).

Sub-Order Pinnipedia. Seals, Eared Seals, and Walruses.

These are marine Carnivores, unable to move readily on land, but coming ashore for breeding purposes. They feed for the most part on fish, molluscs, and crustaceans. Absent from the Tropics, they are represented on most of the coasts in Temperate and Arctic zones. Many are markedly gregarious.

The upper parts of the limbs are included within the skin and general contour of the body. There are five well-developed digits connected by a web of skin. In the hind-foot the first and fifth toes are generally stouter and longer than the rest. There are no clavicles. The tail is very short.

The small milk-teeth are shed or absorbed before or immediately after birth. The incisors are always fewer than $\frac{3}{3}$; there are no carnassials; the back teeth have pointed cusps often sloping slightly backwards.

The brain is large and well-convoluted. The eyes are large and prominent, with a flat cornea. The external ear is small or absent.

The cæcum is very short. The kidneys are divided into lobules. The mammæ are two or four in number, and lie on the abdomen.

Family Otariidæ—Eared or fur-seals, connecting the Pinnipeds with the Fissipeds. The hind-feet can be turned forward and used on land in the usual fashion. The palms and soles are naked. There is a small external ear. The testes lie in an external scrotum.

The sea-lion *Otaria*, $\frac{3,\ 1,\ 4,\ 1\text{–}2}{2,\ 1,\ 4,\ 1}$, supplies the seal-skin of commerce.

Family Trichechidæ—Walruses, intermediate between the Otariidæ and the seals. The hind-feet can be turned forwards and used on land. The upper canines form large tusks; the other teeth are small, single-rooted, and apt to fall out; those generally in use are $\frac{1\,1\,3\,0}{0\,1\,3\,0}$, but the dentition of the young is $\frac{2,\ 1,\ \text{pm. and m. } 5}{2,\ 1,\ \text{pm. and m. } 4}$. There are no external ears.

The walrus or morse, *Trichechus*.

Family Phocidæ—Seals, the most specialised Pinnipeds. The hind-limbs are stretched out behind, and the strange jumping movements on land are effected by the trunk, sometimes helped by the fore-limbs. The palms and soles are hairy. There are well-developed canines, the upper incisors have pointed crowns, there are $\frac{5}{5}$ back teeth. There is no external ear. The testes are abdominal.

The common seal (*Phoca*), $\frac{3\,1\,4\,1}{2\,1\,4\,1}$; the grey seal (*Halichœrus*), the monk seal (*Monachus*), the large elephant-seal (*Macrorhinus leoninus*).

Sub-Order Creodonta (extinct).

In Eocene and early Miocene strata, in Europe and America, there are remains of what seem to be generalised Carnivora, ancestral to the modern types, and apparently related to Insectivora as well. Those included in the sub-order Creodonta have strong canines but no single

carnassials, while the molars are often like those of Marsupials. The brain seems to have been small.

Examples:—*Hyænodon*, *Pterodon*, *Proviverra*, *Arctocyon*.

Order 7. Insectivora.

This order includes hedgehog, mole, shrews, and related mammals. There is much diversity of type, so that a statement of general characters is very difficult.

Most Insectivores run about on the earth; the mole (*Talpa*), and others like it, are burrowers; *Potamogale*, *Myogale*, and others are aquatic; *Tupaia* and its relatives live like squirrels among the branches; and the aberrant "flying Lemur"—*Galeopithecus* takes swoops from tree to tree.

Most feed on insects, but *Galeopithecus* and some other arboreal forms eat leaves as well, the moles eat worms, *Potamogale* is said to feed on fish.

The body is usually covered with soft fur, but the hedgehog (*Erinaceus*) is spiny, and so to a less extent is *Centetes*, the ground-hog of Madagascar. The digits, usually five in number, are clawed, and the animals walk in plantigrade or semi-plantigrade fashion. In most, the mammæ are thoracic or abdominal; in *Galeopithecus*, there are two pairs in the axillary region.

The cranial cavity is small; the skull is never high; the facial region is long; the zygomatic arch is slender or absent. Except in *Potamogale*, there are clavicles.

There are more than two incisors in the mandible. The enamelled molars have tuberculated crowns and well-developed roots. In many cases it is not easy to distinguish the usual division of the teeth into incisors, canines, premolars, and molars, but in many the dentition is typical—3, 1, 4, 3 = 44.

The cerebral hemispheres are smooth and leave the cerebellum uncovered; the olfactory lobes are large; the corpus callosum is short and thin. Thus, as regards the brain, the Insectivora represent a low grade of organisation.

Except in *Galeopithecus*, the stomach is a simple sac; the intestine is long and simple, but the vegetarian forms

have a cæcum. In most, there are odoriferous glands, axillary in shrews, but usually near the anus.

The testes are inguinal or in the groin, or near the kidneys, not in a scrotum. The penis may be pendent from the wall of the abdomen, but is usually retractile. There is a bicornuate or two-horned uterus. Except in *Galeopithecus*, several offspring and usually many are born at once.

The allantoic placenta is discoidal and deciduate. There is a provisional yolk-sac placenta.

Insectivora are represented in the temperate and tropical zones of both hemispheres, but not in S. America nor Australia.

Sub-Order Insectivora Vera:—Insectivores with free limbs suited for movement on land, climbing, burrowing, or swimming. "The upper and lower incisors are conical, unicuspidate or with basal cusps only, the lower not pectinated."

Examples:—the hedgehogs (*Erinaceus*), throughout Europe, Africa, and most of Asia, dentition $\frac{3}{2}\frac{1}{1}\frac{3}{2}\frac{3}{3}$; the shrews (*Sorex*), in Europe, Asia, and N. America, dentition $\frac{4}{2}\frac{1}{0}\frac{2}{1}\frac{3}{3}$; the moles (*Talpa*), throughout the Palæarctic region; the tail-less tenrec (*Centetes*) of Madagascar; the S. African golden moles (*Chrysochloris*); the African jumping shrews (*Macroscelides*); the Oriental tree-shrews (*Tupaia*).

Sub-Order Dermoptera:—represented by the very divergent *Galeopithecus*, which almost requires an order for itself. The fore- and hind-limbs are connected by a parachute, and the animals can glide from tree to tree, "sometimes traversing a space of seventy yards with a descent of only about one in five." The upper and lower incisors are compressed, multicuspidate, the lower deeply pectinated. Two species of this genus live in the forests of the Malayan region. They are nocturnal, and feed on leaves and fruits. The dentition is $\frac{2}{3}\frac{1}{1}\frac{2}{2}\frac{3}{3}$. There are numerous skeletal peculiarities.

Order 8. Chiroptera—Bats.

Bats are specialised Mammals related to Insectivores. They have the power of flight, the fore-limbs being modified as wings. The wing is mainly due to an extension of the skin stretched between the very long fingers. The fold of skin usually begins from the shoulder, extends along the upper margin of the arm to the base of the thumb, thence between the fingers, and along the sides of the body to the

hind-legs or even to the tail, Contrasted with the wing of a bird, that of a bat has a rudimentary ulna beside a long curved radius, a wrist with six bones, five free digits with long metacarpals on the four fingers. The shoulder-girdle is very strong, there is a long curved clavicle, a large triangular scapula, a long coracoid process; the presternum bears a slight keel on which are inserted some of the muscles used in flight. The thumb is always clawed; the other digits are unclawed, except in most frugivorous bats where the second digit bears a claw.

The hind-limb is relatively short and weak, the pelvic girdle is also weak, and in most cases the pubic symphysis is loose in the males, unformed in the females. The knee is turned backwards like the elbow, the ankle has a cartilaginous prolongation or calcar which supports the fold of skin between limb and tail, the five toes are clawed.

The vertebral column is short, there is little mobility between the vertebræ, neural spines are absent behind the third cervical except in Pteropidæ, the caudal vertebræ are very simple. The ribs are usually flat. The maximum dentition is $\frac{2133}{3133}$; the milk-teeth are very different from the permanent set. All the bones are slender, and have large medullary canals.

The cerebral hemispheres are smooth and leave the cerebellum uncovered. The spinal cord is at first very broad, but narrows rapidly behind the neck. The sense of touch is remarkably developed in the hot skin of the wing, the large mobile external ears, the whisker hairs of the snout, and in the strange plaited "nose-leaves" around the nostrils. Even when deprived of sight, hearing, and smell, bats will fly about in a room without striking numerous wires stretched across it.

The temperature of the body is high. The testes are abdominal or inguinal; the penis is pendent. The uterus is simple, with cornua generally short. There is usually but one offspring at a time. The mammæ are thoracic, generally post-axillary. As in Insectivora, the yolk-sac forms a provisional yolk-sac placenta, and the allantoic placenta is discoidal and deciduate.

Fossil Chiroptera occur in Upper Eocene strata, but are quite like the modern forms.

The two sub-orders of bats may be contrasted as follows:—

MEGACHIROPTERA.	MICROCHIROPTERA.
Frugivorous bats, usually large.	Usually insectivorous bats, small in size.
The molars have smooth crowns, with a longitudinal groove.	The molars have cusped crowns, with transverse grooves.
The thumb is clawed, and generally also the second digit.	In the hand the thumb only is clawed.
The tail, if present, is below, not bound up with the interfemoral membrane.	The tail, if present, is bound up with the interfemoral membrane, or lies along its upper surface.
The pyloric part of the stomach is in most cases much elongated.	Except in one family the stomach is simple.
Found in warm and tropical parts of the Eastern hemisphere.	Found in the tropical and temperate regions of both hemispheres.
Examples:— The "flying foxes" or fox-bats (*Pteropus*), large, tail-less bats, distributed from Madagascar to India, Ceylon, Malaya, S. Japan, Australia, Polynesia. The largest species (*P. edulis*) measures five feet across its spread wings. Dentition, $\frac{2}{2}\frac{1}{1}\frac{3}{3}\frac{2}{3}$. In India, *Cynopterus marginatus* is very common. *Xantharpyia ægyptiaca* inhabits the Pyramids. *Notopteris macdonaldi* from New Guinea, has a very long tail.	Examples:— The horse-shoe bats (*Rhinolophus*), the common pipistrelle (*Vesperugo pipistrellus*), the genus *Vespertilio* with four British species, *Vampyrus spectrum* a large Brazilian form, which seems to have been erroneously credited with blood-sucking habits, the common vampire (*Desmodus rufus*) an American bat—a formidable blood-sucker.

Order 9. Lemuroidea. Lemurs.

Opinions differ as to whether the monkey-like animals known as Lemurs should be ranked with monkeys as a sub-order of Primates or referred to a separate order. In many ways they are primitive and divergent. Thus, they differ from the monkeys (Anthropoidea) in the following characteristics:—The orbit opens freely into the temporal fossa (except in *Tarsius*); the lachrymal foramen lies outside the orbit; the first pair of upper incisors are separated in the middle line (except in *Chiromys*); the cerebral hemispheres are but slightly convoluted and do not completely overlap the cerebellum; "the middle or transverse portion of the colon is almost always folded or convoluted on itself;" there may be abdominal mammæ; the uterus is bicornuate; the placenta is diffuse. The dentition of Lemurs varies greatly; in some it is $\frac{2}{2}\frac{1}{1}\frac{3}{3}\frac{3}{3}$.

The Lemurs are small, furry, monkey-like quadrupeds. Many are nocturnal, all arboreal. They feed on fruits and leaves, on eggs and small animals. Seven genera live in Madagascar, three genera occur in the African continent, and other three genera are represented here and there in Oriental forests as far east as the Philippines and Celebes.

As remains of extinct Lemurs are found in Europe and N. America, the distribution of the order is now greatly restricted, and no less than thirty out of the total of fifty species are confined to Madagascar. Wallace concludes from the distribution of Lemurs that there must have been "a large tract of land in what is now the Indian Ocean, connecting Madagascar on the one hand with Ceylon, and with the Malay countries on the other. About the same time (but perhaps not contemporaneously) Madagascar must have been connected with some portion of Southern Africa; and the whole of the country would possess no other Primates but Lemuroidea." Whether this be altogether true or not, it is certain that the Lemurs are absent from regions where once they lived, that most of the modern forms are found (like the Marsupials) on an island, that this insulated race has evolved in several specialised directions, that outside of Madagascar the Lemurs maintain their existence on a few other islands, or by hiding in the forests.

There are three chief types :—

(*a*) That of the Lemuridæ, *e.g.*, in Madagascar *Lemur*, and the large *Indris* (2 feet long), in Africa *Galago*, in Malay *Nycticebus*, in India and Ceylon *Loris*.

(*b*) *Tarsius*, a specialised Indo-Malayan type with many peculiarities, *e.g.*, the calcaneum and navicular are elongated like the calcaneum and astragalus in the frog.

(*c*) *Chiromys*, the Aye-Aye, a specialised Madagascar type, with many peculiarities, *e.g.*, with incisors like those of Rodents, and with a very much attenuated middle finger.

Order 10. Anthropoidea. Marmosets, New World Monkeys, Old World Monkeys, Anthropoid Apes, Man.

This order includes five families.

Family 5.	Hominidæ.	Man.	
4.	Simiidæ.	Anthropoid Apes.	Old World
3.	Cercopithecidæ.	Baboons.	Catarrhine.
2.	Cebidæ.	American Monkeys.	New World
1.	Hapalidæ.	Marmosets.	Platyrrhine.

The following characteristics are generally true.

The body is hairy, least so in man; the dentition is diphyodont and heterodont; the incisors do not exceed $\frac{2}{2}$; the molars are $\frac{3}{3}$ except in the marmosets where they are $\frac{2}{2}$;

the axis of the orbit is directed forward, and the orbit is closed off from the temporal fossa; the clavicles are well-developed; the radius and ulna are never united; the scaphoid, the lunar, and usually the os centrale remain distinct from one another; there are usually five fingers and five toes, but the thumb may be absent or rudimentary; the big toe is opposable except in man, and has a flat nail except in the orang; the thumb is usually more or less opposable; the cerebral hemispheres have numerous convolutions and overlap the cerebellum; the stomach is simple except in *Semnopithecus* and its relatives, in which it is sacculated, and there is a cæcum which is often large; there are two mammæ on the breast; the uterus is simple; the testes lie in a scrotum; the placenta is meta-discoidal, being developed by the concentration of the villi from a diffuse area into a well-defined disc.

Some of the characteristics in which the Anthropoidea differ from Lemuroidea may be re-emphasized:—the orbit is separated from the temporal fossa by a bony partition; the lachrymal foramen is situated within the margin of the orbit; the median upper incisors are in contact; the cerebral hemispheres are richly convoluted and hide or almost cover the cerebellum; "the transverse portion of the colon extends uninterruptedly across the abdomen;" the mammæ are never abdominal; the uterus is not bicornuate but simple; the placentation is meta-discoidal.

Family 1. Hapalidæ (= Arctopithecini). Marmosets.

The marmosets are the smallest monkeys, being no larger than squirrels. They live in companies in the Neotropical forests, especially in Brazil, and feed on insects and fruit.

Their dentition $\frac{2\,1\,3\,2}{2\,1\,3\,2}$ is distinctive, for other Anthropoidea have $\frac{3}{3}$ molars. There is a broad septum between the nostrils, as in the other New World monkeys; the external auditory meatus is not bony. The tail is long, hairy, and non-prehensile. The arms are not longer than the legs; there are no cheek-pouches nor ischial callosities. The thumb or pollex is long but not opposable; all the digits have a pointed claw except the great toe or hallux which is

very small. The marmosets often bear three young ones at a birth, whereas the other monkeys usually bear but one. There are two genera *Hapale* and *Midas*.

Family 2. Cebidæ (= Platyrrhini). American Monkeys.

In the American monkeys the nose is flat, with a broad internarial septum. They occur throughout tropical America, but are most at home in Brazil. All are arboreal, and many have prehensile tails. The digits have nails, not claws; the thumb, though not opposable, is divergent from the fingers, except in the spider-monkey—*Ateles*—in which it is rudimentary. The skull is rounded, and the frontals form a V-shaped suture with the parietals. The dentition is characteristic, for there are six back teeth; the formula being 2133.

Examples:—The howling-monkeys (*Mycetes*), with large vocal organs protected by the expanded mandibles, and with an inflated hyoid bone forming a resonating chamber; the sakis (*Pithecia*) with very long tail; *Nyctipithecus; Chrysothrix:* the spider-monkeys (*Ateles*) with exceedingly prehensile tail; the capuchins (*Cebus*), so often imported into Europe.

Family 3. Cercopithecidæ (=Cynomorph Catarrhini). Old World dog-like Apes.

The Old World apes of this family are still quadrupeds, and the snout or muzzle often justifies the term Cynomorph or dog-like. There is a narrow internarial septum, to which the term Catarrhine refers. The dentition is like that of the anthropoid apes and man, 2123. The external auditory meatus is bony. The thumb is opposable, except when it is rudimentary as in *Colobus*. The tail is not prehensile. Over the rough surfaces of the everted ischia the skin forms callosities often brightly coloured. The breast-bone is narrow. The cæcum has no vermiform appendix.

In the sub-family Cercopithecinæ, there are cheek-pouches, the stomach is simple, the fore- and hind-limbs are almost equal.

Examples:—the African baboons (*Cynocephalus*) *e.g.*, the mandrill (*C. maimon*) notable for the bright colours of the face and hips in the adult males. the macaques (*Macacus*) all Asiatic except

the Barbary ape (*M. inuus*) of N. Africa and Gibraltar; the African *Cercopithecus*.

In the sub-family Semnopithecinæ, there are no cheek-pouches, the stomach is sacculated in a complex fashion, the hind-limbs are longer than the fore-limbs.

Examples:—the sacred Indian apes (*Semnopithecus*), the African *Colobus*, and the proboscis monkey (*Nasalis*) of Borneo.

Family 4. Simiidæ (=Anthropomorph Catarrhini). Anthropoid Apes.

The Old World apes of this family are the Gibbons (*Hylobates*), the Orangs (*Simia*), the Chimpanzees (*Troglodytes* or *Anthropopithecus*), and the Gorillas (*Gorilla*). As they are the highest apes and nearest to man, they are called Anthropoid.

These apes are less like quadrupeds than the others; they have no distinct tail nor cheek-pouches. Only in the Gibbon are there ischial callosities, and these are small. The arms are much longer than the legs. The sternum is broad. The cæcum has a vermiform appendix. As in the lower Old World apes, the dentition is like that of man—2123.

The Gibbons (*Hylobates*) live in S.-E. Asia, especially in the Malayan region. The largest attains a height of three feet. They walk erect with the hands reaching the ground. The skull is not prolonged into a vertical crest. There is an os centrale in the carpus. The hallux is well-developed. They are the highest apes with hints of ischial callosities. They are mainly arboreal in their habits. They feed on fruits, leaves, shoots, eggs, young birds, spiders, and insects. Their voice is powerful. As regards teeth, the gibbons are most like man.

The Orangs (*Simia*) live in swampy forests in Sumatra and Borneo. The males measure over four feet. They walk on their knuckles and on the outer edges of the feet. The skull is prolonged into a vertical crest. There are but slight supra-orbital ridges. The canines are very large. There are twelve ribs as in man, and sixteen dorso-lumbar vertebræ. The larynx is connected with two large sacs which unite ventrally. There are no ischial callosities. They are arboreal in their habits, and make nests in the branches. They are exclusively vegetarian. As regards the structure of the brain, the orangs are most like man.

The Gorillas (*Gorilla*) live in Western Equatorial Africa. They are larger than all other apes, and larger than man, though not over $5\frac{1}{2}$ feet in height. The arms reach to the middle of the lower leg, and the animals walk with the backs of their closed hands and the flat soles of their feet on the ground. The skull is not prolonged into a vertical crest. There are prominent supra-orbital ridges. The canines of the

males are very large. The cervical vertebræ bear very high neural spines, on which are inserted the muscles which support the heavy skull. There are thirteen ribs, and seventeen dorso-lumbar vertebræ. There is no os centrale in the carpus. There are no ischial callosities. They live in families in the forest, and feed on fruits. As regards size, the gorillas are most like man. The males are much larger than the females.

The Chimpanzees (*Anthropopithecus*) live in Western and Central Equatorial Africa. They do not exceed a height of 5 feet. The arms reach a little below the knee. They walk on the backs of their closed hands and on their soles or closed toes. The skull has no high crests. The supra-orbital ridges are distinct. The canines are smaller than in Gorilla or Orang. There is no centrale in the carpus. There are no ischial callosities. They live in families in the forest, and are chiefly arboreal, making nests in trees. They seem to feed on fruits. In the sigmoid curvature of the vertebral column the chimpanzees are most like man.

Family 5. Hominidæ. Genus *Homo*.

The distinctiveness of man from his nearest allies depends on his power of building up ideas and of guiding his conduct by ideals. But there are a few structural peculiarities of some interest.

Man alone, after his infancy is past, walks thoroughly erect. Though his head is weighted by a heavy brain, it does not droop forwards. With his upright attitude, the perfect development of vocal mechanism is perhaps connected.

Man plants the soles of his feet flat on the ground; the great toes are often longer, never shorter than the others, and lie in a line with them; he has a better heel than monkeys have. No emphasis can be laid on the old distinction which separated two-handed men (Bimana) from the "four-handed" monkeys (Quadrumana), nor on the fact that men are peculiarly naked. But "the arms are shorter than the legs, and, after birth, the latter grow faster than the rest of the body."

Compared with the anthropoid apes, man has a bigger forehead, a less protrusive face, smaller cheek-bones and supra-orbital ridges, a true chin, and more uniform teeth (2, 1, 2, 3), forming an uninterrupted horse-shoe shaped series without conspicuous canines.

More important, however, is the fact that the weight of the gorilla's brain bears to that of the smallest brain of an adult man the ratio of 2 : 3, and to the largest human brain the ratio of 1 : 3; in other words, a man *may* have a brain three times as heavy as that of a gorilla. The brain of a healthy human adult never weighs less than 31 or 32 ounces; the average human brain weighs 48 or 49 ounces; the heaviest gorilla brain does not exceed 20 ounces. "The cranial capacity is never less than 55 cubic inches in any normal human subject, while in the Orang and Chimpanzee, it is but 26 and 27½ cubic inches respectively."

But, as Owen allowed long since, there is an "all-pervading similitude of structure" between man and the anthropoid apes. As far as structure is concerned, there is much less difference between man and the gorilla than there is between the gorilla and the marmoset.

The arguments by which Darwin and others have sought to show that man arose from an ancestral type common to him and to the higher apes, are the same as those used to substantiate the general doctrine of descent. The "*Descent of Man*" is the expansion of a chapter in the "*Origin of Species.*" The arguments may be briefly summarised.

(1) Physiological. The bodily life of man is like that of monkeys; both are subject to similar diseases; various human traits of gesture, expression, etc., are paralleled among the "brutes;" reversions and monsters corroborate the alliance sadly enough.

(2) Morphological. The structure of man is like that of the anthropoid apes; none of his distinctions, except that of a heavy brain, are momentous; there are about eighty vestigial structures in his muscular, skeletal, and other systems.

(3) Historical. Certainties in regard to remains of primitive man are few, but his individual development reads like a recapitulation of ancestral history.

To many, man seems too marvellous to have been naturally evolved, to others the evidence seems insufficient, but if the doctrine of descent is true for other organisms, it is likely that it is true for man also.

As to the antiquity of the human race, it is certain that men lived in Europe in the later stages of the Ice Age, and

there are indications of human life in Pliocene times. But as it is certain that man could not have arisen from any of the known anthropoid apes, and likely that he arose from an ancestral stock common to them and to him, it seems justifiable to date the antiquity of the race not later than the time when the anthropoid apes are known to have existed as a distinct race. This takes us back to Miocene ages.

If man was naturally evolved, the factors in the process require elucidation, but in regard to these we can only speculate. From what we know of men and monkeys, it seems likely that in the struggles of primitive man wits were of more use than strength. When the habits of using sticks and stone, of building shelters, of living in families began—and they have begun among monkeys—it is likely that wits would grow rapidly. The prolonged infancy, characteristic of human offspring, would help to evolve gentleness. But even more important is the fact that among monkeys there are distinct societies. Families combine for protection, the combination favours the development of emotional and intellectual strength. "Man did not make society; society made man."

Finally, be it noted that all repugnance to the doctrine of descent as applied to man should disappear when we clearly realise the great axiom of evolution, that "there is nothing in the end which was not also in the beginning."

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